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A SURVEY OF FARM EGG QUALITY[1]

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Despite available information, the quality of farm eggs continues to present a problem during the summer months. In 1944 the percentage of Grade A eggs at a representative grading station in Manitoba was 92 per cent during the winter months and only 45 per cent in mid-summer. Yet some individual flocks supplying this station remained at the winter level throughout the year. Thus the problem appears largely to be one of failure on the part of some individual producers to apply the information available.

The commercial grading of eggs is performed on the basis of a combination of factors, each of which exerts an influence on the candler in making his decision. The accuracy of grading, which in itself is merely an estimate of the interior quality of the egg, depends upon the keenness of the operator and his awareness of the relationship between various factors observed and the interior quality.

There seems to be some confusion among workers as to the exact importance of some of these factors. Their findings have been reviewed in previous literature (1), (9), (11), (17). Coles (3), pointed out that the two criteria of interior egg quality, namely condition of yolk and of albumen, are related since the degree to which the yolk affects the grade depends on the amount of thick white enclosing it. He admitted, however, that many "seconds" may actually be fresh eggs with abnormal whites. Lorenz and Newlon (8), in a survey of egg quality under ranch conditions, observed that actual interior quality deteriorates more than the estimate of quality by candling. Perry (12) claimed exactly the opposite, namely, that the candling appearance seems to indicate a greater deterioration in quality than has actually taken place. Paulhus and Gwin (10) concluded that the candled appearance of eggs was less reliable than broken-out appearance as a measure of interior quality. However, Almquist (1) stated that although the present method of grading eggs by candling is not accurate enough to make fine distinctions in quality, it is probable that no other method will be devised by means of which eggs can be graded commercially with the same versatility, accuracy and speed.

The relationship between different factors of quality in eggs to the candling appearance, as seen in commercial grading, has not been definitely determined. Correlations have been observed between some of these factors such as yolk shadow and yolk colour, but the independent effect of each in determining the candling grade has not been ascertained.

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The purpose of this survey was to determine through field observations, under conditions that could not be simulated in the laboratory, the relative importance of various production and handling factors affecting the grade of farm eggs and also to find the relation between grade and actual quality, as revealed by routine methods of measurement.

EXPERIMENTAL

During 1945 two investigations were conducted, one in June and another in September, of the quality of farm eggs in a representative area of Manitoba. Twenty-nine farm flocks were included in the June tests, while eleven of these plus seventeen additional flocks were visited in September. Three lots, of one dozen eggs each, were obtained at each visit, as follows: (*a*) fresh from the nest, (*b*) day old, (*c*) three days old. Eggs with sound shells and of uniform size were selected. The eggs were cartoned and taken promptly to a local egg grading station, where they were graded from the standpoint of candling quality by a federal egg inspector, classified as to yolk shadow[1], and broken-out for measurements of interior quality. The proportion of Grade C eggs was so insignificant that, for purposes of analysis, Grades A and B only were considered.

Seventeen of the fifty-seven visits were to flocks kept indoors or on restricted pasture, while the remainder had unlimited range. This provided a means of comparing the quality of eggs produced under two distinct types of management. Feeding practice, frequency of egg-gathering, conditions and time of holding prior to marketing, were carefully noted in the case of each flock.

Immediately upon arrival at the grading station, quality measurements were made. Candling grade and yolk shadow were recorded from the external appearance. After breaking, the yolk colour was obtained, using the Heiman-Carver colour rotor (6). Two measurements of albumen quality were made: (*a*) albumen score, as outlined by Van Wagenen and Wilgus (15) and (*b*) albumen height according to the method of Wilgus and Van Wagenen (16).

The importance of yolk shadow measurement lies in its attributed relation to interior quality. A yolk shadow scale, originally used by the Marketing Service of the Dominion Department of Agriculture, was adjusted to suit the requirements. It consisted of a 4×16 inch metal plate with $\frac{1}{2}$ inch holes in two rows $\frac{1}{4}$ inch apart. There were 15 holes $\frac{1}{2}$ inch apart in each row. Over one row of holes were placed a series of coloured filters, combinations of different shades of gelatin paper; these resulted in a range of colour from light straw to dark reddish amber. The other row of holes was left open. The gelatin paper was obtained commercially by name and number as follows:

Light straw	No. 2
Lemon	No. 6
Light amber	No. 10
Amber	No. 12
Dark amber	No. 13

[1] Placing the egg at the aperature of the candling lamp in the usual manner, the yolk shadow is observed through an open hole in the shadow scale. At the same time, through the corresponding filter, is viewed a portion of the egg which does not include the yolk shadow. The latter is then matched with the proper filter.

TABLE 1.—COMPOSITION OF FILTERS OF YOLK SHADOW SCALE

Filter No.	Colour combination	Filter No.	Colour combination
1	1 Light straw	10	1 Light straw 1 Lemon 2 Light amber 2 Amber
2	1 Lemon		
3	1 Light straw 1 Lemon	11	1 Lemon 3 Light amber 3 Amber
4	1 Light straw 2 Lemon	12	2 Light amber 4 Amber
5	3 Light straw 1 Lemon	13	5 Light amber 2 Amber 1 Dark amber
6	1 Light straw 1 Lemon 1 Light amber	14	3 Light straw 1 Light amber 2 Dark amber
7	1 Light straw 1 Lemon 2 Light amber	15	2 Light straw 1 Lemon 1 Light amber 2 Amber 2 Dark amber
8	1 Light straw 2 Lemon 2 Light amber		
9	1 Light straw 1 Lemon 2 Light amber 1 Amber		

The use of coloured filters was necessary due to the association of colour with light transmission in candling. There appeared to be a direct relationship between depth of colour and degree of light transmission. Arranged as shown in Table 1, the filters gave an even gradation of colour as well as a gradual reduction in light transmission from Filters 1 to 15. This arrangement was achieved by using a photoelectric cell and a constant source of light. The various combinations were then checked more accurately by means of a flicker meter, resulting in a gradual reduction in relative light transmission from 0.796 for Filter 1 to 0.185 for Filter 15.

In conjunction with the survey, a controlled experiment was conducted at the University of Manitoba. The object was to determine the effect of green feed on candling grade and interior quality over a storage period of a week. Three groups of hens were trapnested and given, in addition to a basic ration (*a*) plentiful oat and rye pasture, (*b*) cut soaked alfalfa at 3 pounds per 100 birds per day, and (*c*) no green feed, respectively. The eggs were kept from one to eight days in a basement room at about 60° F. The routine measurements of quality were made.

In analysing the data, routine statistical methods were used as outlined by Goulden (5) except where noted as otherwise. In the case of the analysis of variance, due to the unequal frequencies in the sub-classes, the method of "expected sub-class frequencies," described by Snedecor and Cox (13), was used.

TABLE 2.—MEAN VALUES OF FOUR QUALITY FACTORS, BY GRADE, AND MEAN DIFFERENCES BETWEEN GRADES, FOR JUNE AND SEPTEMBER

	June			September		
	A grade	B grade	Mean diff.	A grade	B grade	Mean diff.
Number of eggs	814	269	—	832	363	—
Yolk shadow*	7.64	10.03	2.39	7.57	9.83	2.26
Yolk colour*	15.01	16.72	1.71	13.56	15.48	1.92
Albumen score**	2.17	2.59	0.42	2.27	2.73	0.46
Albumen height***	0.262	0.221	0.041	0.247	0.202	0.045

* Arbitrary units.
** Arbitrary units, 1 to 5 with decreasing albumen quality.
*** Inches.

TABLE 3.—COEFFICIENTS OF CORRELATION BETWEEN FOUR QUALITY FACTORS FOR JUNE AND SEPTEMBER

Variates		Correlation coefficients	
		June	September
Yolk shadow	× Yolk colour	0.4899	0.4245
	× Albumen score	−0.0573	0.2465
	× Albumen height	−0.1951	−0.2799
Yolk colour	× Albumen score	−0.1224	−0.1387
	× Albumen height	0.1113	0.1253
Albumen score	× Albumen height	−0.7982	−0.8789

One per cent level of significance 0.0810.

RESULTS

Relative Importance of Various Quality Measurements with Respect to Grade

The degree of association between yolk shadow, yolk colour, albumen score and albumen height and the candling grade, was measured by means of the Discriminant Function as outlined by Cox and Martin (4). Grades A and B only were involved. Mean differences between grades for each of the four factors, in both June and September, are shown in Table 2.

Correlations between the four factors are given in Table 3. Relative ability of the various factors to differentiate between grades of eggs up to three days of age is revealed in Table 4, in order of discriminating power, namely: albumen height, albumen score, yolk shadow and yolk colour.

The results obtained in Table 4 are based on the data in Tables 2 and 3. These relative values give the discriminating power of each of the factors when the others remain constant, showing their actual theoretical independent effect. Though yolk colour has the smallest relative value it may still have some effect in grading.

Effect of Green Feed on Grade and Interior Quality

The percentages of eggs falling below Grade A, from flocks having restricted and unrestricted green feed, are shown in Table 5. There were approximately the same percentages in the two lots of fresh eggs but the

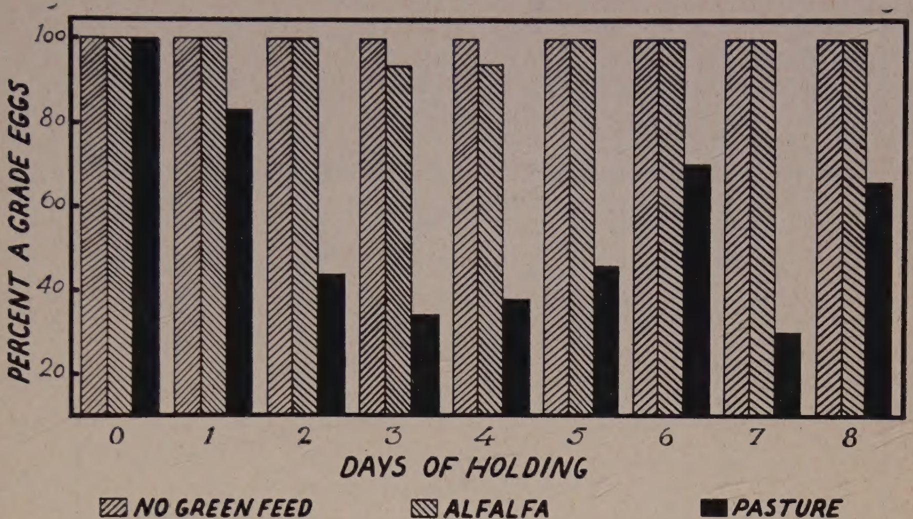

FIGURE 1. Effect of length of holding on grading quality of eggs from birds on three different levels of green feed.

proportion of B's increased more rapidly in the unrestricted flocks until at the third day there were 20 per cent more B grade eggs from the unrestricted flocks. Figure 1 shows a similar trend for the eggs from the controlled experiment held for 8 days. The difference is very definite although it would have been more uniform with larger numbers. Analysis of variance of the albumen score and albumen height showed that there was no difference in albumen quality due to feeding, as has been conclusively proven before. The yolk shadow was darker in the unrestricted flock by 1.58 units and was therefore the result of increased yolk colour which was 15.6 for the unrestricted as compared with 12.8 for the restricted flocks. In the analysis of variance of yolk colour there was a highly significant interaction between ages of eggs and diets of the flocks. This was due to the fact that the B grade eggs from restricted flocks were 2.57 units darker than the A grade eggs but were only 0.83 units darker in the case of the unrestricted flocks. It appeared from this that yolk colour was playing a part in the grading. In the case of the unrestricted flocks, a slight darkening of the yolks above the average, possibly in conjunction with another factor such as weakening of the albumen, resulted in B grade. With the eggs from the restricted flocks, having a lighter yolk colour, considerably more depth of colour was possible before the eggs became B grade.

Table 6 shows a comparison between the eggs in June and September as to quality factors. Here we find a decrease in interior egg quality which is not reflected in the percentage of B grade eggs. However, the yolk colour had decreased in September and consequently did not affect yolk shadow to such an extent.

A noteworthy point is the consistent manner in which the yolk colour became lighter with age. This trend was statistically significant and occurred in the case of the eggs used in the survey as well as in the controlled experiment. It is illustrated in Figure 2.

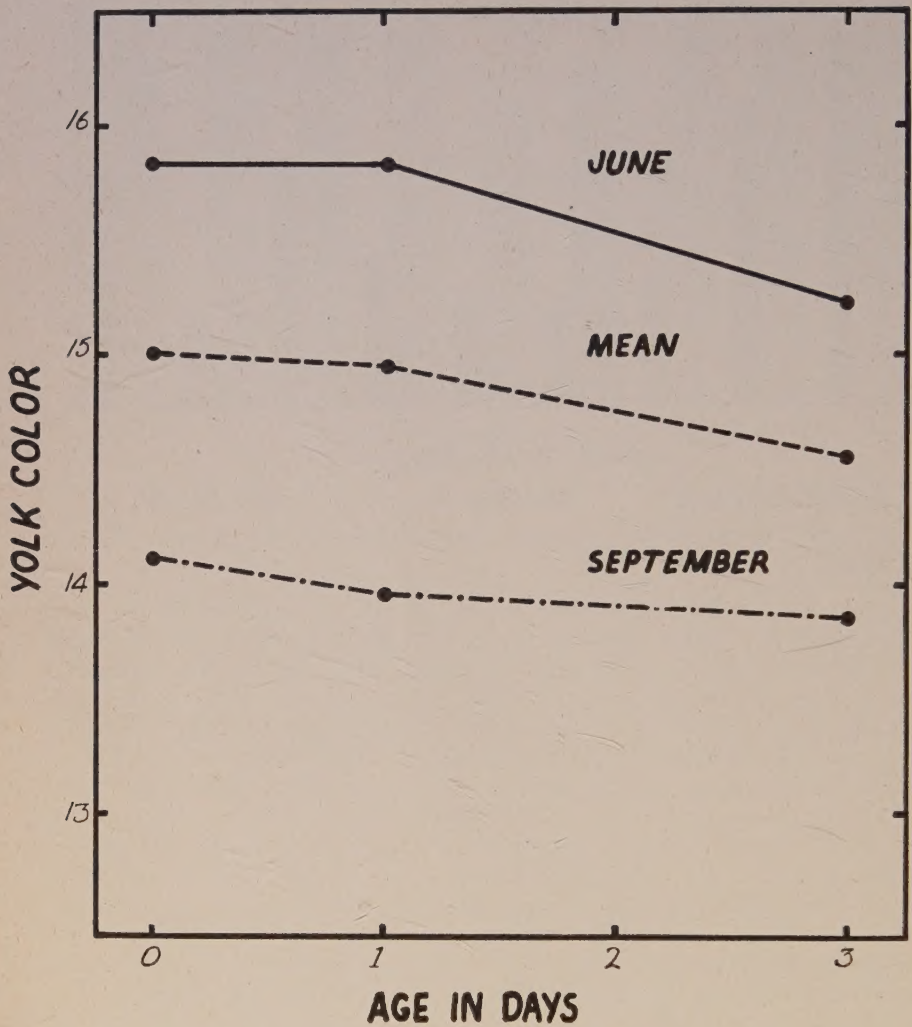

FIGURE 2. Effect of age of eggs on yolk colour.

Relation Between Management and Egg Quality

The seasonal trend of egg quality on Manitoba farms had been observed, from previous records, to decrease from about 92 per cent Grade A eggs during the winter to only 45 per cent in August and September. Sufficient experimentation has been done to establish management factors, such as poor holding conditions, etc., as major factors responsible for such a decline. It was felt, however, that some particular problems might be present in Manitoba due to the large number of small farm flocks.

Several farms were selected during the survey to illustrate the variation which occurs in egg quality between farms. Five of the flocks were rated A, B and C with respect to the way in which different management factors were carried out. Thus a rating of A indicated ideal farm conditions of care, temperature of holding and frequency of gathering and delivery. In

the case of green feed the rating was intended as an indication of the relative amounts consumed by the birds, C indicating the maximum. The ratings of the flocks are given in Table 7. Weekly grading records during 1945 were obtained for these farms from the Manitoba Co-operative Poultry Marketing Association. The average trend of quality for each of these, as shown by the percentage of A grade eggs, is illustrated in Figure 3. This, with Table 7, shows the relation between management and the quality obtained.

Frequency of gathering and temperature of holding seemed to be the most important factors as far as maintaining high quality was concerned. It is interesting to note that dark yolk colour resulting from unlimited pasture did not affect the grade of eggs from Flock 2. In Flocks 3, 4 and 5, when combined with poor conditions of care, it was a factor in influencing the grade.

TABLE 4.—RELATIVE VALUES OF FOUR QUALITY FACTORS IN DIFFERENTIATING BETWEEN GRADES

Variate	Discriminating values	
	June	September
Albumen height	0.213890	0.236919
Albumen score	0.202033	0.218183
Yolk shadow	0.117228	0.063549
Yolk colour	−0.037017	−0.002460

TABLE 5.—COMPARISON OF PERCENTAGE B GRADE EGGS BETWEEN FLOCKS WITH RESTRICTED AND UNRESTRICTED PASTURE

Age	Percentage B grade	
	Restricted pasture	Unrestricted pasture
Nest	8.1	7.6
One day	12.2	26.1
Three days	27.0	47.2
Average	15.9	27.1

TABLE 6.—COMPARISON OF EGG QUALITY MEASUREMENTS IN JUNE AND SEPTEMBER

Factor	June	September
Yolk shadow	8.24	8.02
Yolk colour	15.24	13.88
Albumen score	2.25	2.31
Albumen height	0.254	0.243
Per cent B grade	24.2	23.6

Table 7.—Ratings of five individual flocks according to different management factors

Factor	Ratings				
	Flock 1	Flock 2	Flock 3	Flock 4	Flock 5
General care	A	A	A-B	B	C
Green feed	A	C	C	C	B
Gathering	A	A	B	B	C
Holding	B	A	B	B	C
Delivery	B	B	A	C	C

DISCUSSION

In commercial egg grading the egg is judged by its appearance when held before the candling lamp. Yolk shadow is one of the main criteria used in deciding the grade. Though not in itself a direct measure of egg quality, it is influenced to a certain extent by actual interior quality factors such as albumen condition and yolk colour, albumen condition being the important measure of quality and generally considered as the main cause of variation in yolk shadow. Judgment of egg quality by considering yolk shadow is made on the basis of its attributed association with the above interior quality factors. However, dark yolk colour produces dark yolk shadow, whereas high albumen quality decreases the intensity of yolk shadow. Therefore, deep yolk shadow may indicate a dark coloured yolk, poor albumen quality, or a combination of both. Moderately dark colour of yolks will not influence the yolk shadow if the albumen condition is good enough to offset it. In an egg where the albumen, although slightly weakened, is still of A quality, a dark coloured yolk will tend to indicate a greater deterioration than has actually taken place, judging by the yolk shadow. Thus complete reliance upon the depth of yolk shadow as a basis of judgment of interior quality would lead to some erroneous conclusions.

Variation in albumen quality had a direct effect on the appearance of the egg before the candling lamp, resulting in A, B or C grade. It was observed that dark yolk colour caused a slightly weak albumen to be more apparent than it would have been otherwise. Eggs having an albumen height of 0.300 inches or more would candle as A grade even though the yolk colour was 18 to 20 units; but any weakening of the albumen caused a deeper yolk shadow, giving the grader the idea that the interior quality was worse than actually was the case. For example, the mean yolk colour of the eggs obtained from Flock 2 (Figure 3) in June was 16.13 units. The mean albumen height was 0.272 inches for the nest eggs and 0.252 inches for the three day-old eggs. Four of the thirty-six eggs were B grade. The depth of yolk colour in each of these eggs was 20, 21, 18 and 20 units, respectively and the corresponding albumen heights were 0.261, 0.159, 0.288 and 0.207 inches. When the independent effect of yolk colour was considered, with the albumen in a uniform condition, it was of less importance.

In the reverse direction, if the yolk colour was light, eggs passed as A grade with lower albumen quality than was possible when they had dark yolks. That is, the actual interior quality, as measured by the condition

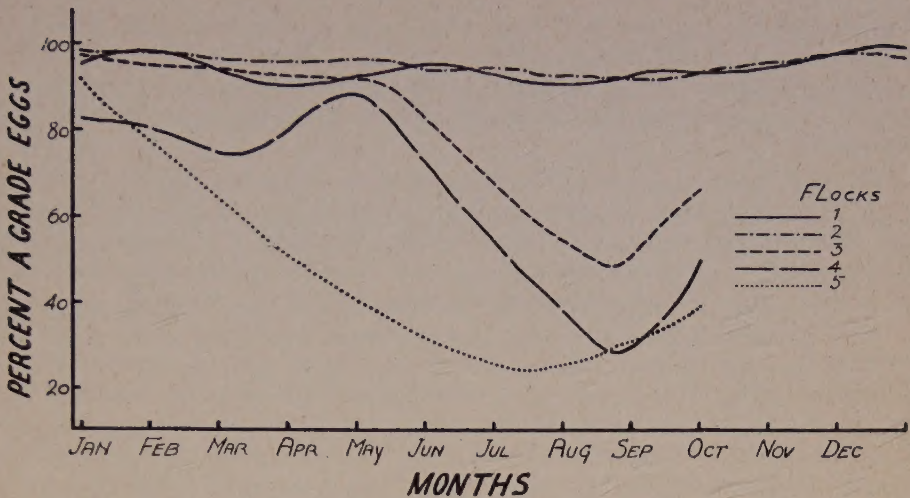

FIGURE 3. Trend of egg quality of five individual flocks during 1945.

of the albumen, had to be considerably lower in order that the eggs would appear as B grade on candling. Eggs from a flock with a mean yolk colour of 16.35 and with a mean albumen height for the three day-old eggs of 0.239 inches, graded 50 per cent B grade, as compared with eggs from Flock 2, with a similar yolk colour but better albumen, which were 11 per cent B grade. In contrast to this, the sample from another flock, where the birds were kept indoors without any green feed, contained 100 per cent A grade eggs. Yet the mean albumen height, although being quite good for the nest eggs (0.280 inches), went down to 0.216 inches for the three day-old eggs. Five of these eggs were below 0.210 inches. However, the yolk colour was quite light; its mean value for the thirty-six eggs was 8.64 units. Similarly the albumen height of the eggs from Flock 1 (Figure 3) declined from 0.273 to 0.209 on the third day, while the mean yolk colour was 8.15. All the eggs in the sample were graded A.

In the light of the above data it is obvious that yolk colour plays an important part in the commercial grading of eggs. Supporting evidence is illustrated in Figure 1 where practically all the B grade eggs were from birds receiving unlimited green feed. The reason for the exceptionally good grade of eggs from Flock 2 (Figure 3) was the quality of the albumen. It was above average for the nest eggs and there was a drop in the mean value of only 0.020 inches in three days. In the case of Flock 1 and other similar indoor flocks the albumen quality was not so good but the light yolk colour made it more difficult to detect deterioration in quality.

The high albumen quality of the eggs from Flock 2 was maintained through frequent gathering and suitable holding conditions. The same grade was obtained by other flocks where the yolk colour was lighter, even though less care was given to the eggs. Depth of yolk colour is neither a necessary indication of inferior egg quality, since it is usually the result of carotenoid pigments in the feed (11), nor is it necessarily associated with poor albumen quality. Canadian consumer demand favours the mild appearance and flavour of winter eggs. It is probably desirable that eggs

with considerable depth of yolk colour and poor or only moderately good albumen quality be placed in B grade on candling. However, the fact that eggs which have the same, or slightly poorer, albumen quality pass the candler as a A grade because their yolk colour is lighter, is not entirely satisfactory.

Practical poultry producers become aware of the greater tendency of eggs from outdoor flocks to grade as B's if the quality is not particularly good. Frequently, instead of improving their methods of gathering and holding eggs they propose keeping their birds indoors, without green feed, thus reducing the yolk colour but not improving the actual quality.

This was well illustrated in the case of a flock, mentioned previously, where, at the time of the visit in June the eggs in the sample were all A grade. On breaking, the mean albumen height for the three day-old eggs was only 0.216 inches, lower than the mean for all the B grade eggs in June. The yolk colour was very light −8.64 units. The temperature of the egg room was 69° F.—the same as the outside temperature. Yet a good grade was consistently obtained for the eggs from this flock. When revisited in September, the birds were running out on pasture. Examination of the weekly grading reports showed a large proportion of B grade eggs.

Comparison of the results for flocks restricted and unrestricted as to amount of green feed yielded an important fact. There was no significant difference in albumen quality. Therefore, the fact that there were 27.1 per cent B grade eggs from the unrestricted flocks as compared with 15.9 per cent for the restricted (Table 5) must be attributed to some cause other than inferior albumen quality. Since the percentage of B grade in the nest eggs was about the same in both cases, and since they increased more rapidly in the case of the unrestricted flocks, it appears that the difference was due to exposure of the darker yolks as the albumen became weaker, causing a darker yolk shadow as seen by the grader. These results have since been confirmed by another worker (2).

In examination of the results of the Discriminant Function it is interesting to note that when the independent effect is concerned, albumen height is the most important factor in grading. Yet the correlation between yolk colour and yolk shadow is quite high. It is difficult to say that any one factor is independent of another in grading. Yolk shadow is the only one which can be measured in candling. Since grading is chiefly an estimation of the condition of the albumen, the only way of doing this is by judgment of the yolk shadow, air cell size, and yolk shape and position. Yolk colour is an incidental factor by which the grader is influenced, unconsciously or otherwise.

It seems that some adjustment in the grading regulations is needed. Elimating green feed from the diet of the birds in order to decrease the yolk colour will probably better the flock owner's financial position but will not help the industry, since low initial quality will show up rapidly during continued storage. Greater emphasis should be given to grading factors other than yolk shadow, e.g. the shape and position of the yolk. If the supporting albumen is weak, the yolk will tend to become flabby and flattened, failing to remain well centered when twirled in candling. Grad-

ing standards might be adjusted slightly, depending on the season of the year. Thus, dark yolk shadow in winter eggs should be viewed with suspicion. The other auxiliary factors relating to the yolk, as well as air cell size, should be given relatively greater emphasis in the summer season when the yolks are darker.

Although public demand favours a mild coloured yolk, the emphasis should still be placed on albumen condition, since that is the real criterion of egg quality. Extremely dark or olive-coloured yolks are, of course, objectionable since they often result from weeds and barnyard offal in the hens' diet. A very satisfactory arrangement appears to be to have the birds indoors until about 2.00 p.m. They will then have received a full ration, consumption of green feed will not be excessive, and a uniform yolk colour of moderate depth will result.

Results of the survey confirm the conclusions of other workers—that frequency of gathering and temperature of holding had a great deal of influence on the grade. In some cases, conditions were fairly satisfactory for short holding but delivery was made only once in eight or ten days; the result was a poor grade. An extensive campaign of education of flock-owners on the proper treatment of perishable products such as eggs would probably help to reduce the extreme ignorance and carelessness displayed.

It was found by Stewart *et al.* (14) that with increasing yolk colour there was a slight tendency toward a lowering of albumen quality. Results from this project did not support their findings. The survey results showed positive correlations between yolk colour and albumen height of 0.1113 in June and 0.1253 in September. The trend was slight but significant and showed that there was no need to expect poorer albumen quality as a direct result of plentiful green feed.

The manner in which the yolk colour became lighter with increased age was observed in the survey data and the control group. In both cases it appeared to be more marked where birds were restricted in amount of green feed. It is probable that this is the result of slight oxidation of the carotenoid pigments in the yolk.

The controlled experiment was carried out for the purpose of eliminating some of the variations which occurred between farms and confirming any conclusions which were drawn from the results of the survey.

SUMMARY

1. A survey of egg quality on Manitoba farms was made during 1945. Twenty-nine farms were visited in June and twenty-eight in September. General information regarding management was obtained, and quality determinations were made on 2,532 eggs. Records of the seasonal trend were obtained in the case of five farms.

2. A controlled experiment at the University of Manitoba poultry plant provided information supplementary to the results of the survey.

3. The order of importance of the independent effect of the quality factors studied, in differentiating between grades is: albumen height, albumen score, yolk shadow and yolk colour.

4. Yolk colour is significantly correlated with yolk shadow, but its effect is influenced by the condition of the albumen. High albumen quality will completely mask normal variations in yolk colour.

5. Unlimited green feed, in the form of pasture, does not have an adverse effect on albumen quality.

6. Yolk colour plays an important part in the grading of eggs, due to its effect on yolk shadow, causing a tendency to exaggerate the deterioration in quality in eggs with dark yolks. Medium or low quality albumen is not as noticeable in candling eggs with light coloured yolks.

7. Differences in frequency of gathering eggs and in temperatures of holding are responsible for a great deal of the variation in egg quality which occurs between farms. Rapid cooling and frequent delivery are also factors of importance.

8. The seasonal drop in egg quality, occurring on many farms, could be largely eliminated by proper methods of management and care.

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EXPERIMENTS IN CONTROL OF THE CARROT RUST FLY (*Psila rosae* L.)[1]

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INTRODUCTION

The carrot rust fly, *Psila rosae* L., an European pest of umbelliferous plants, was first recorded in British Columbia in 1936. Since that time it has spread over all the coastal area, and as a result the growing of carrots and parsnips in field and garden has been seriously affected.

A study of the life-history and control of this insect was undertaken by officers at the Entomological Laboratory, Agassiz, B.C., in 1939 when, after several seasons of experimental work, it was shown that considerable control could be obtained by applying either a 4 per cent calomel-talc dust or by treatment of the foliage with naphthalene. All other materials tried, including DDT, proved unsatisfactory. However, the authors were not satisfied with the control obtained with either of these materials; the cost was too high for commercial crops, and as three or four applications were needed for each of the three generations of the fly that occur in British Columbia, it was laborious. Finally, only 75 to 85 per cent control was obtained even when the insecticides were carefully applied at the correct times, which was very important.

With the introduction of benzene hexachloride it was decided to test this material, as reports of its usefulness and lasting properties as a soil insecticide were most encouraging.

1946 EXPERIMENTS

Benzene hexachloride was first tested against the carrot rust fly in British Columbia in 1946, being compared with seven other formulations of various materials.

The experiments were conducted at Chilliwack where nine beds of carrots each consisting of three rows, twelve feet long and replicated three times, were used. Owing to the late wet spring the seedlings were not up in time to be treated against the first generation. Applications of the various materials were made therefore on July 16, July 25 and August 7, but as the second generation was negligible, as often occurs in hot weather in British Columbia, no satisfactory counts of infestation were possible. However, the plots were left intact to observe whether or not any of the materials applied would remain effective against the third generation.

This generation commenced to emerge on September 4, and continued until frost in early November. Counts of infestation were made October 1, when it was found that all plots, with the exception of those treated with

[1] Contribution No. 2520, Division of Entomology, Science Service, Department of Agriculture, Ottawa Canada.

benzene hexachloride, were infested from 40 to 70 per cent. The benzene hexachloride-treated plots showed only 14 per cent infestation, the injury being quite negligible.

A final examination on November 5 showed the benzene hexachloride plots to average 16 per cent injured carrots, while all the others, including the check plots, were from 75 to 95 per cent infested, and the injury to the roots was severe.

These results demonstrated the remarkable lasting properties of benzene hexachloride, as satisfactory control had been obtained approximately 90 days after the last application—a very important consideration with an insect having an extended emergence and oviposition period.

The benzene hexachloride mat rial used was a 20 per cent "666" dust partly deodorized, w th a gamma isomer content of 2 per cent, supplied by Imperial Chemical Industries, England. For experimental purposes the gamma content was reduced to one-half of one per cent by the addition of pyrophyllite. It was applied at the rate of 1 pound to 200 feet of row in each application, the dust falling on the foliage and ground adjacent to the carrot row.

No tainting as a result of the benzene hexachloride applications was noted when the carrots were subsequently eaten.

1947 EXPERIMENTS

First Generation

In view of the results obtained in 1946, experiments dealing with the control of this insect in 1947 were planned around benzene hexachloride, the object being to determine more closely the number of treatments required and the best method of application.

FIGURE 1. Section of experimental carrot plot, Chilliwack, B.C. Emergence box in centre of 3-row check plot. Note sparser and yellowish foliage in this bed.

Plan

Two blocks of carrots were grown for experimental purposes that year, one at Chilliwack and one at Sardis, some four miles distant. It was known from experience that a high degree of infestation was probable at each location. The soil at both places was a clay loam, closely similar in texture.

At each location the plots consisted of 7 beds, each of three rows of carrots 15 feet long; duplicate plots were used at each location, thus there were four beds of each treatment in the experiment. The rows of the beds were 16 inches apart, and a blank row was left between each bed.

Treatments and Plot Layout, 1947

Chilliwack

15′ (width); 64′ (length)

	15′
1	Crude naphthalene
2	Moth balls
3	BHC in soil
4	BHC 1 foliage app.
5	BHC 2 foliage apps.
6	BHC 3 foliage apps.
7	Check
1	Crude naphthalene
2	Moth balls
3	BHC in soil
4	BHC 1 foliage app.
5	BHC 2 foliage apps.
6	BHC 3 foliage apps.
7	Check

Sardis

15′; 30′

	15′		
3	BHC in soil	7	Check
4	BHC 1 foliage app.	2	Moth balls
5	BHC 2 foliage apps.	1	Crude naphthalene
6	BHC 3 foliage apps.	3	BHC in soil
8	Stove oil	4	BHC 1 foliage app.
1	Crude naphthalene	5	BHC 2 foliage apps.
2	Moth balls	6	BHC 3 foliage apps.
7	Check	8	Stove oil

Materials and Application

Crude naphthalene (Bed 1): This was used as purchased from roofing companies, pulverized when necessary. Four applications at weekly intervals were made, using at the rate of 1 pound per 100 feet of row; 7 ounces per plot per application.

Moth balls (Bed 2): Used as purchased. One ball placed alternately on each side, closely adjacent to the row, 8 inches apart. One application was sufficient as balls last the entire season. Rate of application $1\frac{3}{4}$ pounds per 100 feet of row—12 ounces per bed.

Benzene hexachloride (Beds 3, 4, 5 and 6): The material used was the same as in 1946, being a 20 per cent dust in gypsum, partly deodorized (though still very pungent). It was diluted from its original 2 per cent gamma content with pyrophyllite, to give a one-half of 1 per cent gamma dust. The rate of application used on all beds was approximately 1 pound gamma isomer per acre per application.

In Bed 3 the dust was shaken into the one-inch deep open drill, just prior to seeding. One application only was made, the rate being 11 ounces per 100 feet of row, or 5 ounces per bed.

In Bed 4, the same quantity of dust was shaken into the foliage in one application.

In Bed 5, 2 applications, similar to that on Bed 4, were made at 10-day intervals, while on Bed 6, 3 applications were made to the foliage, also at 10-day intervals.

Bed 7 was in all replications the untreated check plot.

At Sardis an extra bed was added, 8; this was treated with commercial stove oil by means of a knapsack sprayer. Two applications were made using one-quarter gallon per bed or one-half gallon per 100 feet of row.

Timing of Applications

The application of materials was timed to coincide with the appearance of the first generation adults. This emergence was recorded by the appearance of the flies in cages adjacent to the plots. Some of these cages were placed over soil infested in 1946, while others were artificially stocked with puparia early in the spring.

Emergence of first generation flies commenced April 22, reached a peak April 30 and finished May 27.

Time-Table of Applications

Bed	Material	Dates of application
1	Naphthalene	Apr. 24, May 2, May 10, May 17
2	Moth balls	Apr. 24
3	BHC in soil	Mar. 26
4	BHC on foliage	Apr. 24
5	BHC on foliage	Apr. 24, May 5
6	BHC on foliage	Apr. 24, May 5, May 16
7	Untreated check	
8	Stove oil	Apr. 24, May 6

TABLE 1.—EFFECT OF DIFFERENT TREATMENTS UPON INFESTATIONS BY FIRST GENERATION CARROT RUST FLY, 1947

A. Results from Different Districts and from Individual Plots

CHILLIWACK PLOTS

Plot	Treatment	First replication			Second replication			Average
		No. of carrots	No. inf.	Per cent infested	No. of carrots	No. inf.	Per cent infested	Inf. of 2 plots
1	Naphthalene	115	1	0.5	127	3	2.0	1.6
2	Moth balls	120	33	27.5	90	50	55.0	39.5
3	BHC in soil	110	0	0.0	114	1	0.5	0.4
4	BHC 1 app.	120	0	0.0	115	1	0.5	0.4
5	BHC 2 apps.	100	0	0.0	87	0	0.0	0.0
6	BHC 3 apps.	85	0	0.0	91	0	0.0	0.0
7	Check	100	100	100.0	80	60	75.0	88.8

SARDIS PLOTS

Plot	Treatment	First replication			Second replication			Average
		No. of carrots	No. inf.	Per cent infested	No. of carrots	No. inf.	Per cent infested	Inf. of 2 plots
1	Naphthalene	40	3	7.5	100	5	5.0	5.7
2	Moth balls	44	12	27.0	68	33	48.0	40.1
3	BHC in soil	77	5	6.6	59	2	3.0	5.1
4	BHC 1 app.	79	1	1.0	85	0	0.0	0.6
5	BHC 2 apps.	96	3	3.0	33	1	3.0	3.1
6	BHC 3 apps.	82	2	2.5	53	0	0.0	1.5
7	Check	52	47	90.0	80	79	98.0	95.0
8	Stove oil	20	0	0.0	32	0	0.0	0.0

B. Average Infestation of All Plots (Four Replications)

Plot treatment	Number of carrots	Number infested	Per cent infested
Crude naphthalene	382	12	3.1
Moth balls	322	128	39.7
BHC in soil	360	8	2.2
BHC 1 foliage app.	399	2	0.5
BHC 2 foliage apps.	316	4	1.2
BHC 3 foliage apps.	311	2	0.6
Stove oil (Sardis only)	52	0	0.0
Untreated checks	312	286	91.7

At the time of the first application of material the young carrot plants were about 2 inches high and just showing their first forked leaves, being then one month from seeding. Thus, most of the dust applied to the foliage at this time fell on the soil underneath. This occurred to a lessening extent with the second and third applications.

Infestation Record

The first signs of injury were noted May 27 in the check plots, and by June 2 the characteristic droop of the outer leaves, resulting from larval feeding at the roots, was evident.

A preliminary count of the infestation was made June 5 on the Chilliwack plot, 20 carrots from each bed being lifted. The check beds showed 70 per cent infestation, the moth balls 20.5, naphthalene and benzene hexachloride in the soil 2.5 per cent each, while beds 4, 5 and 6, with foliage applications of benzene hexachloride were quite clean.

On June 11 and 12 the main count of infestation was made at both Chilliwack and Sardis. The roots in a yard-long strip, from the centre row of each bed, were pulled and closely examined for maggot infestation. In all cases a root was counted as infested even where only very slight injury was noted. A rather poorer stand of carrots at Sardis was responsible for the smaller count there than at Chilliwack.

Comment on Results

As can be seen from the tables, the infestation of the check plots averaged over 90 per cent, and was so severe that many young seedlings died. In the moth ball-treated plots the infestation occurred chiefly at the tips of the main tap root, and the resulting damage was not nearly so severe; no wilting of the foliage occurred here.

Although the four benzene hexachloride treated beds showed from 0.5 to 2.2 per cent infestation the injury was so light and indeterminate that no damage was done to any roots.

Taste tests made at this time on carrots from the benzene hexachloride beds showed some tainting—the usual musty flavour associated with this material. This was most noticeable in Bed 3, where benzene hexachloride had been put in the drill with the seed.

This tainting remained after cooking in those carrots from Bed 3, but was not evident in those from the foliage-treated beds. The carrots at this time were too small for proper use, and by July absolutely no tainting was discernible from any bed except Number 3.

Second Generation Experiments

The beds were left intact and without further treatments throughout July and August to test residual action of the benzene hexachloride in comparison with the other materials.

The second generation flies started to emerge June 27, reached a peak about July 8 and continued with lessening numbers until early August; a few still continuing to appear irregularly until August 22.

The appearance of second generation adults this year was much more uniform and abundant than has usually been the case in previous years, and from former observations this was probably due to the absence of hot weather. Only 2 days showed a maximum of over 80 degrees F. during the entire emergence period of this generation.

A preliminary examination was made August 22, when larvae and puparia were found in the check and naphthalene beds but none in the benzene hexachloride beds. On September 3 to 6 a complete examination of the infestation on both the Chilliwack and Sardis plots was made. Results from the four replications were in close agreement, but the infestation at Sardis was much lighter as evidenced by the smaller number of carrots affected in the check and naphthalene plots.

The results of the count for the four plots is averaged in Table 2.

TABLE 2.—EFFECT OF DIFFERENT TREATMENTS UPON INFESTATIONS BY SECOND GENERATION (SEPTEMBER 6) CARROT RUST FLY, 1947

Average of Chilliwack and Sardis Plots

Plot	Spring treatment	Number examined	Number infested	Per cent infested
1	Naphthalene	184	103	56.0
2	Moth balls	206	121	58.7
3	BHC in soil	200	0	0.0
4	BHC 1 foliage app.	209	0	0.0
5	BHC 2 foliage apps.	214	0	0.0
6	BHC 3 foliage apps.	229	0	0.0
7	Checks	199	125	62.8
8	Stove oil (Sardis only)	18	8	44.4

It will be seen that complete immunity was obtained from larvae of the second generation in all plots treated with benzene hexachloride 130 days previously, that is in April and May. The effect of the applications of naphthalene evidently had disappeared almost completely by this time.

No difficulty was experienced in distinguishing between first and second generation injury at this time but it was noted that, this year, larvae of the second generation fed chiefly by tunnelling in the carrot. Heretofore second generation larvae had been observed to feed chiefly on the lateral feeding roots, and while a heavy infestation would result in drooping and russeting foliage, the carrots themselves would be little injured by this side feeding. The reason for this change of feeding habit is not known, but is probably related to the temperature and moisture conditions in the soil.

From the foregoing results it is obvious that practically perfect control was effected over two generations of flies, covering a period of about 170 days, from a single application of benzene hexachloride. This confirms the results of 1946.

Effect on Carrots

Tainting at this time was definitely confined to the plots where benzene hexachloride had been incorporated in the soil at seeding time. Absolutely no taint remained in those carrots receiving foliage and soil surface treatments.

A feature of this soil incorporation method was that a constriction occurred on approximately 25 per cent of the carrots in these beds. This constriction occurred one-half inch below the top of the carrot, and reduced the diameter from one-quarter to one-half of its normal size. The location of this ring on the carrot would indicate that it was caused by the layer of benzene hexachloride in the soil at this level.

Third Generation

Emergence

The adult of this generation commenced to appear as early as August 29, the record of emergence being obtained from two soil cages set over infested carrots at Chilliwack. From previous observations it had been

found that the emergence of the flies of this generation covered an extended period, and was only inhibited by frost. It is unusual for any well marked peak to occur, but the first two weeks in September are customarily looked upon as the optimum period of emergence. These conditions obtained in 1947, and flies continued to emerge irregularly until November.

Control Experiments

In order to test still further the lasting properties of benzene hexachloride, the plots were left intact but on the appearance of the third-generation flies, the foliage of one-half of all beds was treated on September 3 with a one-half of one per cent gamma dust (0.5 per cent). The same material and rate was used as in the spring on the Chilliwack plots while on the Sardis plots the quantity was halved, one-quarter pound of dust only being applied to each one hundred feet of row.

Approximately 7 weeks later, on October 20 and 21, examination was made of the infestation in both the re-treated and untreated halves of the plots with the results as presented in Table 3.

TABLE 3.—EFFECT OF DIFFERENT TREATMENTS UPON INFESTATION BY THIRD GENERATION (OCTOBER 20) CARROT RUST FLY, 1947

Chilliwack Plots

AVERAGE OF DUPLICATE TREATMENTS

Plot	Original treatment	Not re-treated			Re-treated BHC Sept. 3		
		Number exam.	Number infested	Per cent infested	Number exam.	Number infested	Per cent infested
1	Naphthalene	121	101	83.4	96	60	62.5
2	Moth balls	102	85	83.3	116	80	68.6
3	BHC in soil	92	22	23.8	119	15	12.6
4	BHC 1 foliage app.	142	41	28.8	124	21	16.9
5	BHC 2 foliage app.	108	25	23.1	134	11	8.2
6	BHC 3 foliage app.	133	22	16.5	155	2	1.3
7	Check	80	60	75.0	73	23	31.5
		Average		45.7	Average		25.9

The results of the counts at Sardis are not included in Table 3 as the plots had been partially destroyed. However, where counts were possible, the results were closely similar to the above, despite the smaller quantity of dust applied.

It will be noted from Table 3 that control from the September application of benzene hexachloride was by no means 100 per cent as had been the case with the spring applications against the first and second generations. No logical explanation can be given for this at the present time. Temperature can hardly have been a factor, as both air and soil means were higher in the autumn than in the spring. A comparison of the averages shows 45.7 per cent infestation from the non-treated half, and 25.9 per cent in the beds of the re-treated portion; so apparently there was an appreciable and definite control.

FIGURE 2 (*top*). Carrots from Plot 3, showing ringing due to incorporation of benzene hexachloride in soil.

FIGURE 3 (*bottom*). Samples of carrots from Chilliwack plots, Sept. 5.

Group 1. Benzene hexachloride on foliage —Plot 4
Group 2. Check, no treatments —Plot 7
Group 3. Benzene hexachloride in soil —Plot 3
Group 4. Naphthalene —Plot 1

FIGURE 4 (*top*). Samples from Chilliwack plots, Sept. 5.
Group 1. Benzene hexachloride on foliage —Plot 4
Group 2. Naphthalene —Plot 1

FIGURE 5 (*bottom*). Carrots showing typical, severe, third generation injury.

The lasting qualities of benzene hexachloride are evidenced by the figures from beds 3, 4, 5 and 6 of the non-retreated half of the plots. Here the benzene hexachloride beds treated in the spring averaged only 23.1 per cent infested, while the other 3 beds (checks, and naphthalene treated, originally), showed 81.1 per cent infestation. Also the degree of freedom from infestation is related to the amount of benzene hexachloride originally applied, as three applications gave greater immunity than either two or one application.

In the re-treated half of the beds the separation of the second generation injury from that of the third was difficult and probably accounts for the high degree of infestation, averaging 54.2 per cent in plots 1, 2 and 7. In plots 3, 4, 5 and 6, this difficulty did not arise as no second generation injury had occurred.

To properly evaluate the effectiveness of benzene hexachloride against the third generation it will be necessary in future to provide later sowings of carrots free from first or second generation injury.

In connection with this third-generation control we have several records of late-sown carrot plots, treated in early September with benzene hexachloride, that were entirely free from infestation.

SUMMARY

Experiments on the control of carrot rust fly at Chilliwack and Sardis in 1946 and 1947 are described, covering all three annual generations.

The possibility of obtaining a very high degree of control with only one application of benzene hexachloride against two generations of this insect are demonstrated.

The importance of dosage and method of application are shown. Foliage and ground surface treatments gave satisfactory freedom from tainting, while soil incorporation resulted both in tainting and direct injury by the chemical.

Tests for taint on both raw and cooked carrots conducted by the Home Economics Division of the University of British Columbia, Vancouver, in February, 1948, on stored samples grown in plots at Chilliwack, confirm the above findings. Only where soil incorporation of benzene hexachloride had been made was any tainting recorded.

Further experimentation is indicated; but from the results obtained to date, a cheap, simple and very efficient control has been provided for the use of carrot growers.

ACKNOWLEDGMENTS

These experiments were based on a co-ordinated plan of root maggot control incepted by A. G. Dustan, Officer-in-Charge of Vegetable Insect Investigations, Ottawa, and his assistance in planning this work is hereby acknowledged.

The junior author, H. G. Fulton, had entire charge of the growing and treating of the carrots and the making of infestation counts. The planning and general layout of the tests were designed by both officers.

THE EFFECT OF THE GRANULATION OF SINGLE CEREAL GRAINS ON THE INCIDENCE OF PRESSURE NECROSIS IN POULT STARTER MASHES[1]

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One of the problems confronting turkey raisers in Western Canada has been the rather high incidence of pressure necrosis in young poults started on certain poult starter mashes. Very little reference is to be found in the literature concerning this problem.

Conklin and Maw (1, 2) described a necrotic condition of the beak of battery brooded chicks which resulted from the impaction of food. They concluded that it was "apparently due to close confinement and finely ground food." Gutteridge[3] also describes a similar condition but offered no explanation as to its cause. The condition as observed in turkey poults occurred in both battery brooded and floor brooded lots. Food became impacted around the edges of both upper and lower mandibles within 48 hours after feeding commenced and gradually built up until a condition similar to Figure 1 resulted. Conklin and Maw (1) state that the impaction usually commenced at about four weeks with chicks and that by the sixth week either upper or lower mandible may have been sloughed off. The author has never observed this sloughing off of the mandibles in turkey poults even when a serious condition was allowed to persist for as long as 14 days. A necrotic condition of the upper mandible can be seen in Figure 1.

Preliminary tests undertaken at this Station during 1943, 1944 and 1945 indicated that the problem might be one of the granulation of the cereal grain portion of the ration. It was noted that there was a wide variation in the fineness of grind in commercial poult starters. These preliminary tests indicated that those starter mashes with the highest percentage of floury material resulted in the greatest incidence of pressure necrosis.

During 1946 an effort was made to check a large number of commercial poult starters both by feeding tests and by mechanical analysis. It was not possible to test all starter mashes for pressure necrosis at one time. They were, however, tested in groups of four, but the basis for necrosis ratings were the same in all cases. Day-old poults in groups of from 26 to 34 were used in the tests which were conducted in an electrically-heated battery brooder. The poults were individually checked each morning for a ten-day period.

Samples of each of the starter mashes used in the feeding tests were analysed mechanically and it was found that the portion of the mash which passed through a 3/64 inch round holed sieve varied from 45 per cent to 90 per cent. Generally speaking those starter mashes which had a large percentage of fine particles gave the highest pressure necrosis ratings.

[1] Contribution from the Poultry Division, Dominion Experimental Farms Service, Canada.
[2] Officer-in-Charge, Poultry.
[3] Unpublished data, Poultry Division, Central Experimental Farm, Ottawa.

FIGURE 1. This figure indicates a serious case of pressure necrosis as experienced in the 1946 test.

There were, however, three samples which did not entirely fit into this picture. One of these gave a much lower rating than expected and the others gave higher ratings than expected. Figure 1 shows a serious case of impaction as produced in this test.

To further clarify this problem an experiment was set up at this Station in 1947 to test the effect of single cereal grains on pressure necrosis.

EXPERIMENTAL METHODS

Day-old turkey poults were randomized throughout the compartments of the battery brooder and were fed on starter mashes which contained only one cereal grain ingredient. Wheat and oat groats were the cereal grains used in this test. Five different degrees of granulation were included for each of these. Included in the test also was a standard poult starter which contained all three cereal grains—wheat, oats and barley.

The basal ration was similar in all cases (see Table 1) and made up fifty per cent of the starter mash. The basal ration was made up as follows: wheat bran 10 per cent; alfalfa meal 20 per cent; fish meal 25 per cent; meat meal (50 per cent protein) 30 per cent; skim milk powder 10 per cent; ground limestone 2 per cent; salt 2 per cent; fish oil (400D-2400A) 1 per cent; manganese sulphate 1 pound per ton; riboflavin 8 grams per ton.

The poults were examined individually each morning for a 10-day period and the rating on pressure necrosis recorded. A somewhat different set of ratings were used than those used in 1946, to permit of smaller differences being recorded.

Composite samples of the different grinds of cereal grains used in the starter mashes were set aside for mechanical analyses.

RESULTS AND DISCUSSION

Table 2 shows the results of the mechanical analysis of the cereal portions of the various starters. It will be noted that the percentage passing through a 3/64 inch screen decreases progressively in the case of both wheat and oat groats.

TABLE 1.—COMPOSITION OF RATIONS USED IN PRESSURE NECROSIS TEST

Ration No.	Basal ration	Wheat					Oat groats					Ground barley	Pulverized whole oats
		Grind No. 1	Grind No. 2	Grind No. 3	Grind No. 4	Grind No. 5	Grind No. 1	Grind No. 2	Grind No. 3	Grind No. 4	Grind No. 5		
	%	%	%	%	%	%	%	%	%	%	%	%	%
W-1	50	50	—	—	—	—	—	—	—	—	—	—	—
W-2	50	—	50	—	—	—	—	—	—	—	—	—	—
W-3	50	—	—	50	—	—	—	—	—	—	—	—	—
W-4	50	—	—	—	50	—	—	—	—	—	—	—	—
W-5	50	—	—	—	—	50	—	—	—	—	—	—	—
O-1	50	—	—	—	—	—	50	—	—	—	—	—	—
O-2	50	—	—	—	—	—	—	50	—	—	—	—	—
O-3	50	—	—	—	—	—	—	—	50	—	—	—	—
O-4	50	—	—	—	—	—	—	—	—	50	—	—	—
O-5	50	—	—	—	—	—	—	—	—	—	50	—	—
Control	50	—	—	—	20	—	—	—	—	10	—	15	5

TABLE 2.—MECHANICAL ANALYSIS OF CEREAL GRAIN PORTION OF POULT STARTERS USED IN PRESSURE NECROSIS TEST

Wheat Samples

Sample No.	Size of particles				
	Larger than 6/64 inch	Between 5/64 and 6/64 inch	Between 4/64 and 5/64 inch	Between 3/64 and 4/64 inch	Finer than 3/64 inch
	%	%	%	%	%
Wheat–1	0.0	0.45	2.03	13.68	83.84
Wheat–2	0.06	4.79	4.13	22.38	68.64
Wheat–3	0.14	4.89	18.88	27.04	49.05
Wheat–4	3.00	23.75	18.08	27.75	27.42
Wheat–5	6.93	33.97	23.04	19.11	16.95

Oat Groat Samples

Sample No.	Size of particles				
	Larger than 6/64 inch	Between 5/64 and 6/64 inch	Between 4/64 and 5/64 inch	Between 3/64 and 4/64 inch	Finer than 3/64 inch
	%	%	%	%	%
Oats–1	1.46	12.24	19.12	16.94	50.24
Oats–2	1.62	15.38	20.81	19.76	42.43
Oats–3	3.88	16.68	32.94	15.61	30.89
Oats–4	4.85	25.25	27.36	16.23	26.31
Oats–5	6.96	33.17	26.70	13.10	20.07

Table 3 shows the pressure necrosis rating obtained by feeding the starter mashes and the corresponding figure for the percentage of particles smaller than 3/64 inches in the cereal grain portion of that starter mash. Necrosis ratings below 10 should not be considered of significance in practical poult feeding. It is evident that, as the per cent of cereal grain particles smaller than 3/64 inch increases, the pressure necrosis rating increases in the case of both oat groats and wheat. On a statistical basis the within correlation is + 0.96.

Fine oat groat particles contribute more to the problem than was generally believed. This is evident from a study of ration Wheat–3 and Oats–1. In both cases the percentage of ground grain passing through a 3/64 inch screen was approximately 50 per cent but the pressure necrosis rating for ration Wheat–3 was 11.2 compared to a rating of 24.7 for ration Oats–1. It should also be mentioned here that the cereal grains used in this test were ground in a portable electric grinder similar to commercial electric coffee-grinders. This machine gave a more granular product than is produced by a hammermill, there being less powdered material. It is possible that cereal grains processed by a hammermill would produce a higher incidence of pressure necrosis than that indicated since more of the material in the last column of Table 2 might be of a powdered nature.

TABLE 3.—COMPARISON OF PRESSURE NECROSIS RATING AND PER CENT OF FINE PARTICLES IN CEREAL PORTION OF RATION

Ration No.	Pressure necrosis rating	Percentage of cereal grain particles smaller than 3/64 inch
W–1	44.9	83.84
W–2	29.3	68.64
W–3	11.2	49.05
W–4	4.2	27.42
W–5	2.2	16.95
O–1	24.7	50.24
O–2	23.6	42.43
O–3	17.9	30.89
O–4	6.6	26.31
O–5	5.1	20.07
Control	6.8	

The results of this test, while they indicate a strong positive correlation between the per cent of fine particles in the cereal grain portion of poult starter mashes and the incidence of pressure necrosis, do not preclude the possibility of there being other nutritional factors which may have a bearing upon this problem.

SUMMARY

Wheat and oat groats, in various degrees of granulation, were tested individually, in turkey poult starter mashes, for a comparison of the incidence of pressure necrosis. There is a very strong positive correlation between the per cent of the ground cereal grains which passes through a 3/64 inch round hole sieve and the incidence of pressure necrosis when these ground cereals are fed in a poult starter ration.

Under the conditions of this test, starter mashes, with wheat as the sole cereal grain ingredient, produced significant pressure necrosis when 49 per cent or more of the wheat was ground finer than 3/64 inch. In the case of oat groats significant pressure necrosis was recorded for all rations in which this figure was 30 per cent or more.

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PHYSICAL PROPERTIES RELATED TO STRUCTURE OF STE. ROSALIE CLAY AND THEIR SEASONAL VARIATION[1]

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INTRODUCTION

The importance of structure in soils has long been recognized as a factor influencing fertility. In recent years the description, measurement and mechanism of this property have begun to receive well-warranted attention, and several lines of approach have been followed.

The direct sieving of field samples described by Keen (10), the wet sieving techniques of Tiulin (19), Yoder (21) and others, the micro-aggregation studies of Baver and Rhoades (3), Demolon and Henin (8) and Cole and Edlefsen (7) have placed the emphasis upon the size and distribution of soil aggregation. On the other hand the percolation and infiltration measurements of Slater and Byers (18) and Musgrave (13) have given evidence of the nature of the soil channels from information on the permeability of the soil to water. Finally, there are those techniques which seek to measure the actual porosity, and its size-distribution in the manner suggested by Donat (9) and many others.

No single method gives a complete picture, but together they throw considerable light upon that complex and highly important property, soil structure.

Studies of this kind for Quebec soils are almost non-existent. A preliminary survey of methods and their applicability to Ste. Rosalie clay was started here in 1943 and in 1944 the work was extended to observe and measure the extent of changes which might be expected to take place on this soil type during the growing season. An attempt has also been made to study the various factors responsible for structure changes in this soil and to assess their relative importance and interplay.

Ste. Rosalie clay (6) is found over a fairly large section of the St. Lawrence plain centred upon the Island of Montreal and extending from the United States border on the south to the Laurentians on the north and from somewhat east of the Yamaska River to the Ontario boundary.

It is a clay of medium to heavy texture, developed from lacustrine marine clays deposited by the Champlain Sea, which is quite fertile and responds well to good management. However, it is known to become very hard and intractable under careless handling. Provision of proper drainage is an important factor in its successful management.

The 1944 experiments were done on a 5-acre pasture field a half-mile south of St. Clet, P.Q. (about 35 miles west of Montreal). Samples were taken on five different occasions during the summer, each time from eight different locations upon the field. The eight locations, called A – H in the following text, were laid out at the beginning of the experiments in May.

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[1] Contribution from the Department of Physics, Faculty of Agriculture of McGill University, Macdonald College, Que., Canada. Journal Series No. 241.

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On subsequent occasions samples were taken at the same eight locations, each time on soil which had hitherto been undisturbed by previous sampling. Thus it was possible to observe the changes that took place throughout the season.

The physical properties measured were: Percentage of moisture at the time of sampling; percentage of moisture required for saturation; the volume weight of the field sample; the pore space (both capillary and non-capillary) of the field sample; the rate of water percolation through field samples; the proportion of soil retained by various sieves using the wet-sieving technique (both fresh and air-dried samples were used), and micro-aggregation, which measures the proportion of soil particles smaller than 0.05 mm. which are aggregated into granules larger than 0.05 mm.

Analyses were also made to determine the organic matter content of the various samples as well as the proportions of sand, silt and clay. The measurements were made upon samples taken from 4 to 6 inches below the ground level, herein called the "surface" region and also from 12 to 15 inches below ground level, called the "subsoil" region.

METHODS OF ANALYSIS

A. Volume Weight (Apparent Density)

Sampling was done with a specially-made instrument of seamless steel tubing similar to the Bradfield sampler (2), fitted with removable copper liners of length 7.2 cm. and internal diameter 7.5 cm.

A rectangular hole approximately 20 inches square with vertical sides was first dug at the sampling point. The sampler, containing its copper liner, was then forced into one side-wall by means of an automobile jack resting against the opposite wall. After sufficient penetration, the sampler was loosened for removal, the copper liner containing the soil core was pushed out of the steel shell and placed in a waxed cardboard box for transfer to the laboratory. Here the soil projecting from the two ends of the liner was sliced off with a sharp knife thus leaving a definite known volume for further experiment. The large cylinder of soil showed no evidence of compression, and supported by its $\frac{1}{8}$-inch copper cylinder, it was easily handled. Volume weight (apparent density) was obtained by dividing the over-dry weight of soil by the internal volume of the copper cylinder.

B. Pore Space

(a) Total Porosity

If the apparent density is known, and the absolute density of the soil sample is measured, then the total percentage of pore space (P) may be calculated from the formula:

$$P = 100\left(1 - \frac{d}{D}\right)$$

where d and D are the apparent and absolute densities, respectively.

In this work the absolute density of the soil grains was measured by means of a pycnometer in the usual way. Samples were boiled vigorously during the procedure to get rid of occluded air. For best results deter-

minations should have been made upon composite samples taken from the actual contents of the individual copper cylinders. These cylinders were being used for a number of other measurements, so to save time, determinations were made upon soil sliced as excess from the ends of the copper cylinders.

Only about 45 determinations of absolute density were made for the 80 or more cylinders used in the experiments, this being justified by the fact that at a given location the absolute densities were found reasonably constant throughout the season. The apparent and absolute densities thus being known, the total porosity at each sampling point was easily found.

(b) Capillary and Non-Capillary Porosity

After tying a single layer of thoroughly boiled tracing linen over the lower end of the cylindrical sample it was placed in water to within $\frac{1}{2}$ inch of the top of the cylinder and left over night for saturation. On the following morning it was placed upon a glass plate to prevent drainage while weighing and the saturated weight was quickly determined, after which it was set upon a suction table of the kind suggested by Leamer and Shaw (11). A suction of 40 cm. of water was applied until the samples reached constant weight (36 hours or more) after which they were weighed, transferred to the oven and dried at 105° C. The volume of water retained against 40 cm. of water suction is taken to represent the capillary pore space; this value, subtracted from the total porosity, is called the non-capillary pore space.

Due to swelling of the samples upon saturation some variability of results will be introduced because of different initial moisture contents. Consequently the question arises as to whether or not the soil should be saturated in the field before sampling. As these experiments were designed to observe the changes throughout the season, sampling has been done in the present instance at the existing field moisture, times being chosen when the soil was reasonably moist.

C. Moisture Content

(a) Field Moisture

The percentage of moisture under field conditions was measured by weighing the cylindrical samples as soon as they reached the laboratory and again after oven drying.

(b) Moisture Required for Saturation

This was found by overnight saturation, as described above, followed by thorough drying.

Both the above measurements are expressed as a percentage of oven-dry weight.

D. Percolation Rate

Permeabilities of the soil samples were measured immediately after overnight saturation. Each sample, in its copper cylinder, and with the base covered by a single layer of size-free tracing linen, was placed on a Buchner funnel and a strip of rubberized friction tape was wrapped round the upper rim of the cylinder to form a shallow cylindrical reservoir 1 cm.

deep. This was kept filled with water at room temperature. Water passing through the sample for the first ten minutes was discarded; that transmitted during the next hour was collected, measured and recorded as a measure of the percolation rate.

This technique was chosen for its simplicity and it neglects a number of important variables. Long continued leaching would doubtless influence flocculation through the removal of important ions with a consequent change in the time rate of percolation; the presence of soil air will have its effect; micro-biological action will also change the rate of percolation if this activity is permitted. In the simple method used no attempt was made to measure or control these factors—indeed it is probable that uncontrollable variations such as roots, worm holes, etc., would have been equally or possibly more important.

E. Wet Sieving

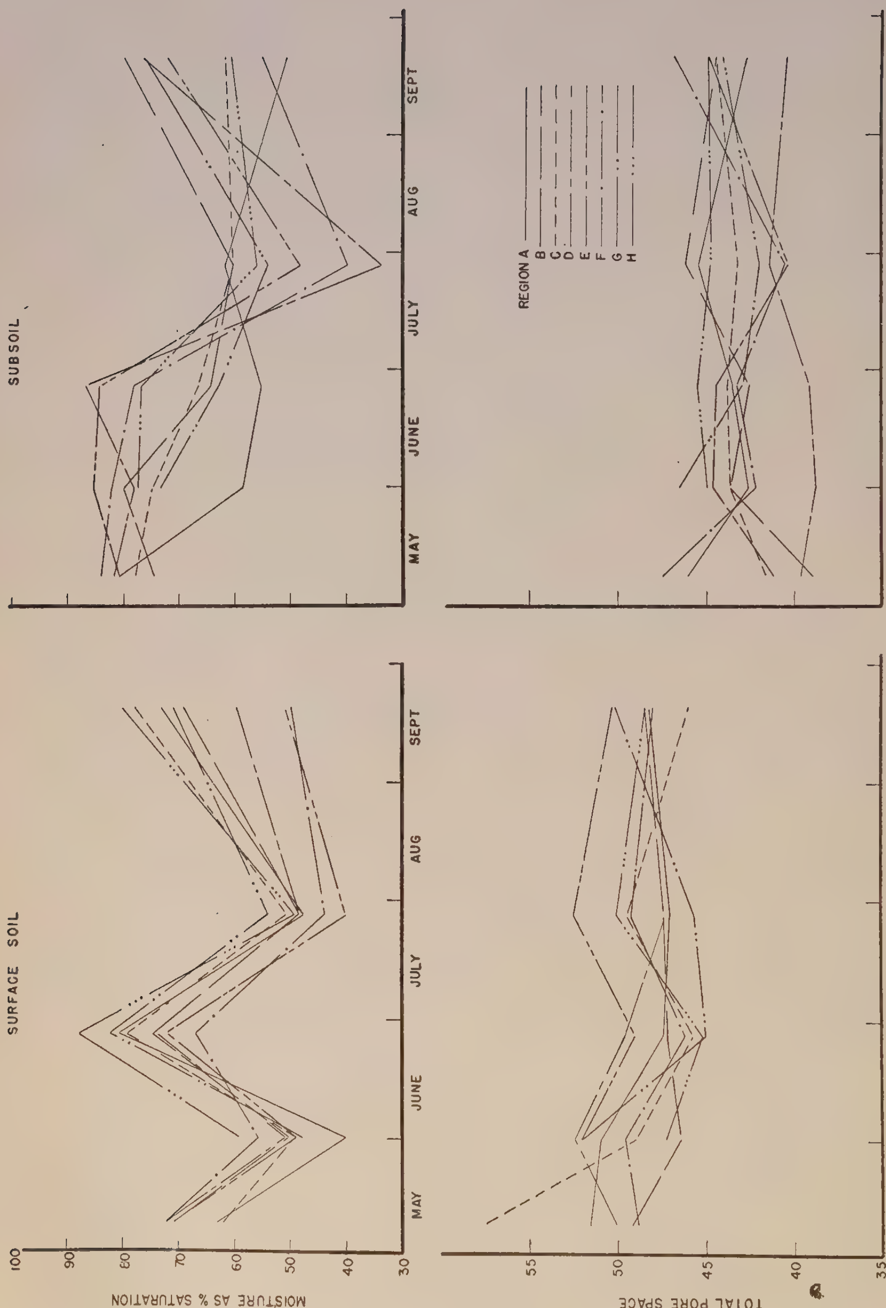
(a) Samples at Field Condition

The size distribution of aggregates of the larger sizes was measured by a modified Yoder method. A 40 gm. sample of fresh soil, selected in the field from the rectangular hole in which the volume weight samples were taken, was broken by hand to a maximum size of about 8 mm. diameter. This was wet slowly by capillarity for 1 hour, then covered with water to slake for 24 hours after which it was placed on the top sieve ready for sieving. A nest of three 8-inch diameter sieves was used, consisting of a No. 10 with a 1.98 mm. opening, a 14 mesh (U.S. series equivalent No. 16) and a 28 mesh (U.S. series equivalent No. 30) one above the other, attached to a rocker arm which produced a vertical stroke of 4.5 cm. and made 68 oscillations per minute. The sieves were oscillated vertically in water for 5 minutes and the portions remaining on each sieve were then washed into beakers, dried and weighed. The results were corrected for moisture in the original samples and expressed as percentage of the oven-dry soil.

The measurements thus include along with the aggregates a number of unaggregated particles, for, if the soil had been completely dispersed, many of the larger soil grains would have been retained by the No. 30 and No. 16 sieves. None would have remained on the No. 10 sieve. The figures reported are thus actually higher than they should be for aggregates of the smaller sizes but this fact is of small consequence for the purpose in hand. Measurements indicated that there was no significant difference in clay content of the aggregates retained on the No. 10 and No. 30 sieves.

(b) Wet Sieving of Air-dry Samples

For this measurement soils from the test regions were air-dried in the laboratory for a week or more. Larger clods were crushed by a light rolling-pin action so as to pass a 4 mm. round hole sieve. Thirty-gm. samples of well-mixed composite were weighed out for wetting and slaking. To avoid the explosive shattering which commonly occurs when air-dry soil is plunged into water, two methods of wetting were used. In the first method samples were placed in a round-bottom flask and evacuated for 10 minutes. While still under vacuum, water was run in to cover the sample. Slaking time was 24 hours. In the second method samples were placed in open beakers and a 2-inch circle of heavy blotting-paper was


SURFACE SOIL
SUBSOIL
MOISTURE AS % SATURATION
TOTAL PORE SPACE
100
90
80
70
60
50
40
30
55
50
45
40
35
MAY
JUNE
JULY
AUG
SEPT
REGION A
B
C
D
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G
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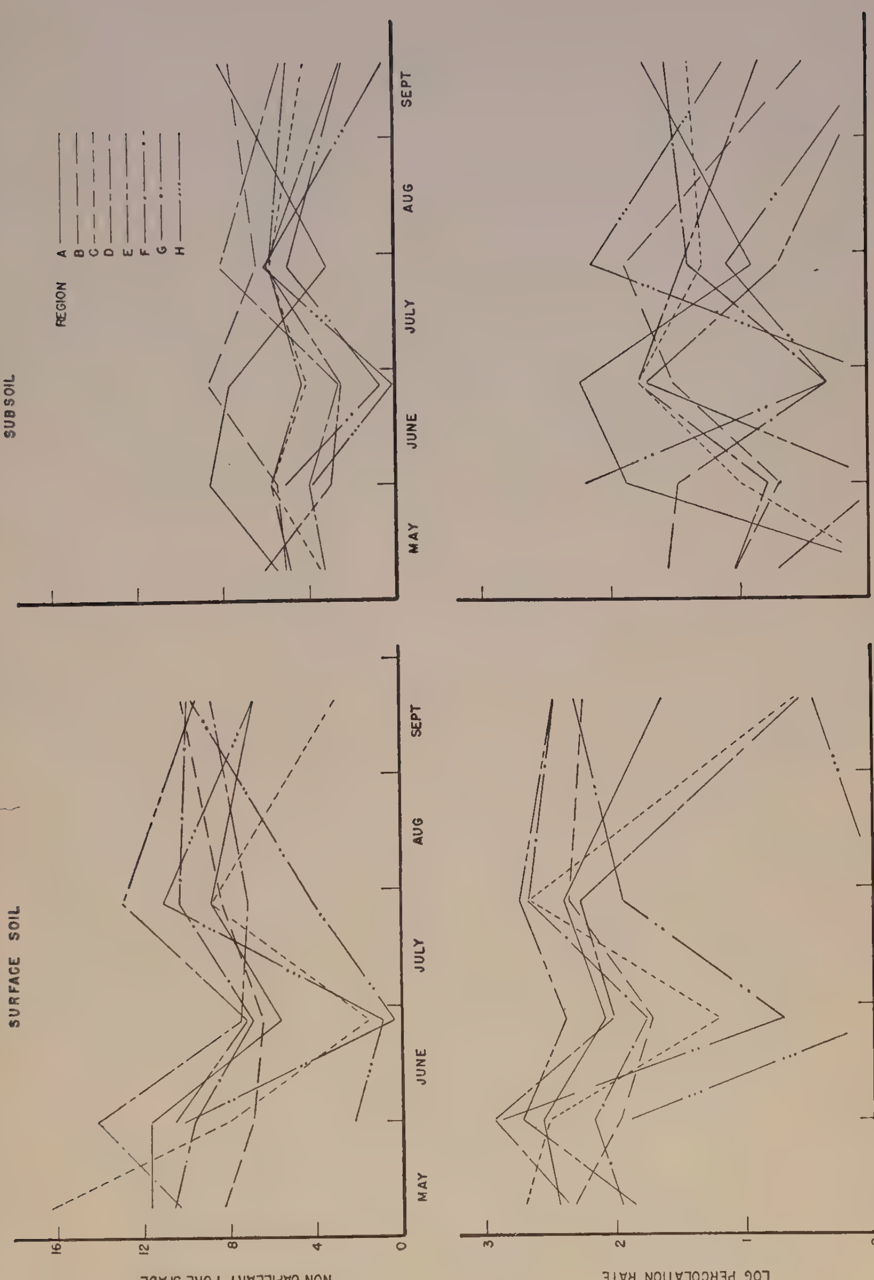

Figure 1. Seasonal Variations of a Number of Physical Properties of Ste. Rosalie Clay.

placed directly on the sample. A little water was then sprayed on the blotting-paper and the whole covered with a damp cloth and left to stand for 18 hours. At the end of this time water was added to cover the sample and an additional 24 hours was allowed for slaking.

Vacuum-wetting of the necessary duplicate samples is a tedious process and showed no appreciable advantage over the simpler method. Most of the observations reported were, therefore, obtained by the latter method. Sieving technique was the same as that already described.

F. Micro-Aggregation and Structural Coefficient

The method used for this determination was similar to that described by Middleton (12). When the soil was analysed at field moisture 30 gm. samples were weighed as soon as possible after sampling (approximately 4-6 hours), the soil having been broken by hand to 4 mm. diameters or less. To these samples water was added and 1 hour slaking allowed. The sample was then placed in a glass cylinder of height 45 cm. and diameter 6 cm. Water was added to make a total volume of 1000 ml. and the whole inverted 30 times and allowed to settle. After 60 seconds 20 cc. were withdrawn by pipette from a 15 cm. depth and transferred to an evaporating dish.

The remainder of the sample was then thoroughly dispersed by the Bouyoucos method for 5 minutes using 5 cc. of saturated sodium oxalate and 5 cc. of N/10 NaOH and again 20 cc. were withdrawn at a depth of 15 cm. after 60 seconds of sedimentation. The pipette contents were in each instance dried and weighed. The two weights being designated x and y gm., respectively, the structural coefficient is calculated as $\frac{(y - x)\,100}{y}$ per cent in the manner described by Russell (17).

G. Organic Matter Content

(a) Removal of Organic Matter by Hydrogen Peroxide

An attempt was made to measure the organic matter by treatment with hydrogen peroxide as suggested by Robinson (15). Unfortunately this method was not suited to this clay because sample weights were actually found to increase upon continued treatment with hydrogen peroxide. This may be due to the presence of iron or manganese compounds which become progressively oxidized. No measurements were made to verify this supposition but the method was abandoned in favour of loss on ignition.

(b) Loss on Ignition

It has been assumed, for the range of samples included in this experiment, that loss on ignition will be a reasonable measure of organic content. Samples of approximately 5 grams each were oven dried and then ignited in a muffle furnace at 550° C.–600° C. for 5 hours. Loss on ignition was calculated as a percentage of oven-dry weight. A few random samples were done in duplicate to check the accuracy of measurement but most values quoted represent single determinations.

H. Mechanical Analysis

Mechanical analyses were carried out upon soil taken from the cylindrical cores. The hydrometer method of Bouyoucos (4) was used upon 25-gm. samples, treated with sodium oxalate and sodium hydroxide. Dispersion was for 10 minutes and settling times of 5 minutes and 2 hours were used for the determination of silt and clay. Sand percentage was obtained by difference.

I. Field Observations

In addition to the above measurements notes were taken at sampling time of the size and character of the soil aggregates. Further observations of crumb structure, etc., were also made on several occasions by six independent observers after the various samples had been air-dried for about a week.

EXPERIMENTAL RESULTS

Experimental results are summarized in Table 1, many measurements needed in its preparation having been omitted. Measurements of wet-sieving were all done in duplicate, both upon samples fresh from the field and also after air drying. To save space the latter are not included; average values of the former appear in the table. Data for May 6 are incomplete because in two instances slight changes in technique were found advisable.

The headings in the table are, in general, self-explanatory.

DISCUSSION

Seasonal Changes

The seasonal changes which took place were examined by means of graphs, several of which are shown in Figure 1. A considerable variation in moisture content at the various sampling dates may be observed. Sampling was necessarily limited to periods when the soil could be handled reasonably well, i.e., neither too wet nor too dry. Thus the actual range of moisture content during the summer was much greater than the range shown.

It may be seen that as the soil became drier the total pore space in the soil increased. It may also be seen that the non-capillary pore space increased relatively more than the total pore space whenever the soil became drier. Since the non-capillary pore space has the greater average cross section it should increase the ease of water flow through the soil. That this is indeed true may be seen from Figure 2, the graph connecting percolation rate and non-capillary pore space.

There is a considerable variation in each of the properties measured at different parts of the field on any one sampling date. This is not unusual and only serves to emphasize the well known fact that careful and thorough sampling must be done if "representative" values are being sought.

While large fluctuations are readily seen, no progressive alteration of any of the properties shown in Figure 1, with advance of the season, is evident. One might look for changes in other properties, for example, the

TABLE 1.—PHYSICAL PROPERTIES OF STE. ROSALIE CLAY—MAY TO SEPTEMBER, 1944

Date and region	Moisture at time of sampling, %	Moisture as percentage of saturation	Micro-aggregation, %	Volume weight (gm./cc.)	Total pore space, %	Capillary pore space, %	Non-capillary pore space, %	Percolation rate (ml./hr.)	Soil retained by various sieves after 5 minutes of wet sieving field moist samples, %			Sand, %	Silt, %	Clay, %	Loss on ignition, %
									1.98 mm.	1.19 mm.	0.59 mm.				
MAY 6															
Surface															
A	26.0	63.7	—	1.26	51.5	39.8	11.7	271	—	—	—	39.2	25.0	35.8	7.31
B	27.9	71.0	—	1.32	49.1	40.8	8.3	210	—	—	—	26.0	23.2	50.8	6.03
C	34.0	62.3	—	1.10	57.4	41.1	16.3	500	—	—	—	31.2	27.0	41.8	12.80
D	28.4	72.5	—	1.28	50.1	39.6	10.5	226	—	—	—	40.4	22.4	37.2	8.17
E	29.5	71.0	—	1.24	51.0	43.0	8.0	71	—	—	—	38.6	23.8	37.6	9.38
F	27.6	71.7	—	1.33	48.8	38.2	10.6	89	—	—	—	44.8	21.2	34.0	7.32
Subsoil															
A	26.5	80.8	—	1.47	46.0	40.4	5.6	Nil	—	—	—	16.2	23.4	60.4	4.18
B	18.6	74.7	—	1.67	38.9	33.7	5.2	11	—	—	—	54.2	9.8	36.0	2.15
C	21.3	78.0	—	1.60	41.6	38.0	3.6	Nil	—	—	—	42.6	15.4	42.0	2.70
D	20.7	81.9	—	1.64	39.5	36.1	3.4	11	—	—	—	62.6	7.6	29.8	1.91
E	21.7	80.5	—	1.60	41.1	34.9	6.2	5	—	—	—	42.8	14.2	43.0	2.44
F	29.0	84.0	—	1.44	47.4	42.4	5.0	36	—	—	—	13.6	20.2	66.2	3.63
JUNE 1															
Surface															
A	16.7	40.3	73.6	1.26	51.0	39.3	11.7	365	58.6	11.2	7.9	40.6	29.0	30.4	7.11
B	17.5	50.3	72.8	1.38	46.4	39.5	6.9	94	51.0	13.1	11.2	29.6	23.8	46.6	6.56
C	20.3	46.5	83.0	1.31	49.0	40.9	8.1	320	60.6	11.6	11.5	43.0	14.2	42.8	9.30
D	21.4	51.0	72.0	1.21	52.5	38.3	14.2	870	63.5	13.1	8.3	39.4	22.4	38.2	9.35
E	21.0	49.3	69.0	1.22	52.1	41.5	10.6	520	46.9	12.1	12.1	40.6	25.6	33.8	9.88
F	21.0	56.0	58.9	1.31	49.5	39.8	9.7	147	61.8	9.4	6.7	46.6	18.8	34.6	7.61
G	22.4	47.8	—	1.20	52.1	42.0	10.1	760	67.4	18.0	8.7	33.4	27.6	39.0	11.70
H	23.0	59.2	—	1.43	47.2	45.0	2.2	78	69.5	11.8	9.0	9.8	21.0	69.2	5.98
Subsoil															
A	15.6	58.7	77.3	1.57	42.5	33.8	8.7	75	19.3	12.8	12.9	37.8	22.6	39.6	3.27
B	21.8	80.2	79.3	1.54	43.6	38.0	6.6	5	29.4	18.4	14.9	22.2	18.2	59.6	3.26
C	20.5	75.0	79.0	1.56	43.5	37.6	5.9	10	18.5	16.6	15.9	27.4	18.4	54.2	4.11
D	18.0	78.3	78.2	1.65	38.7	34.6	4.1	6	15.8	13.5	12.1	51.2	10.2	38.6	2.23
E	25.4	85.6	84.4	1.50	44.6	41.5	3.1	Nil	38.0	19.5	14.2	18.4	18.6	63.0	3.54
F	20.6	82.3	81.4	1.59	42.2	36.3	5.9	30	20.5	16.0	15.1	50.4	8.6	41.0	2.23
G	24.5	73.5	—	1.43	46.6	41.4	5.2	155	34.6	16.6	13.0	13.4	23.0	63.6	4.46
H	24.5	77.7	—	1.47	44.9	40.9	4.0	10	60.8	12.5	6.4	18.2	22.4	59.4	4.11
JUNE 26															
Surface															
A	27.8	81.1	82.0	1.36	47.4	41.8	5.6	123	60.0	11.8	7.5	34.0	23.2	42.8	7.20
B	26.3	74.9	74.4	1.39	47.1	40.7	6.4	51	62.1	8.5	5.5	37.4	24.2	38.4	7.21
C	27.9	79.8	70.4	1.39	45.8	44.3	1.5	16	37.1	11.2	9.2	38.4	25.9	35.7	9.06
D	29.6	74.3	66.8	1.30	49.5	42.0	7.5	105	60.5	10.1	7.8	42.0	25.5	32.5	8.78
E	28.4	63.0	88.4	1.30	49.0	41.8	7.2	240	54.5	11.8	8.6	38.8	25.7	35.5	9.20
F	24.1	67.3	61.3	1.40	46.1	39.2	6.9	58	59.0	6.2	3.8	43.2	24.9	31.9	6.69
G	29.2	82.8	74.4	1.37	45.0	44.8	0.2	5	50.4	12.9	10.6	38.2	22.2	39.6	9.85
H	27.9	88.6	58.0	1.48	45.3	44.5	0.8	Nil	26.2	14.9	16.4	0.4	20.4	78.2	3.72

JUNE 26—*Continued*

Subsoil															
A	16.6	55.5	71.0	1.52	43.5	35.7	7.8	165	21.9	22.7	18.6	35.4	16.0	48.6	3.26
B	17.5	64.6	60.5	1.56	42.6	33.8	8.8	32	28.3	18.7	14.7	44.2	14.6	41.2	2.66
C	19.6	66.9	85.5	1.55	43.8	39.6	4.2	60	26.6	24.8	19.3	16.2	24.1	59.7	3.78
D	21.8	87.2	64.0	1.64	39.1	36.4	2.7	58	19.3	13.0	11.2	40.0	12.9	47.1	2.32
E	24.8	84.5	74.1	1.53	44.5	41.9	2.6	53	28.3	18.4	14.8	17.2	20.1	62.7	3.84
F	22.2	78.4	58.7	1.56	43.2	38.8	4.4	2	9.2	11.8	14.8	40.4	18.3	41.3	2.51
G	19.9	63.0	82.0	1.53	42.9	42.2	0.7	2	32.6	21.8	17.0	9.4	21.2	69.4	3.75
H	26.4	77	73.5	1.46	45.6	45.5	0.1	Nil	48.0	13.0	8.4	3.0	20.8	76.2	4.28
JULY 25															
Surface															
A	16.7	47.9	83.0	1.39	47.0	38.2	8.8	245	46.9	15.0	13.3	33.0	24.4	42.6	6.93
B	17.5	48.8	78.0	1.37	47.3	39.0	8.3	225	59.0	10.9	8.1	31.6	26.8	41.6	7.34
C	20.7	51.0	88.3	1.32	49.4	40.6	8.8	480	51.2	15.3	14.3	18.6	24.4	57.0	7.50
D	17.9	48.8	75.5	1.35	47.2	40.1	7.1	185	48.3	12.9	11.0	37.8	25.8	36.4	8.93
E	18.1	40.2	81.7	1.22	52.5	39.6	12.9	537	65.8	10.6	6.6	38.2	24.8	37.0	9.88
F	16.9	44.0	70.0	1.32	49.2	38.9	10.3	448	43.4	11.6	11.8	44.8	22.0	33.2	7.74
G	18.4	54.4	85.0	1.46	45.7	41.6	4.1	86	54.0	12.7	10.5	12.2	24.6	63.2	5.43
H	18.1	49.5	78.5	1.37	50.0	38.9	11.1	1290	38.6	16.6	16.7	12.0	21.8	66.2	5.19
Subsoil															
A	19.8	61.9	86.5	1.50	45.4	42.2	3.2	8	41.9	26.2	18.0	17.0	19.4	63.6	4.08
B	19.2	60.4	93.4	1.48	46.1	39.6	6.5	74	43.2	27.4	16.6	10.8	21.6	67.6	3.62
C	16.8	60.6	92.5	1.55	43.2	37.3	5.9	19	33.5	29.3	19.8	26.2	16.6	57.2	3.65
D	8.5	33.9	77.8	1.59	41.4	33.2	8.2	27	19.7	14.2	13.2	50.8	10.0	39.2	2.33
E	11.9	48.3	82.3	1.63	40.4	34.4	6.0	5	54.1	17.6	8.7	40.8	15.0	44.2	2.71
F	9.5	39.9	48.0	1.62	40.6	34.7	5.9	25	4.7	5.5	7.5	58.2	9.8	32.0	1.89
G	14.8	54.2	74.2	1.57	42.0	37.0	5.0	13	20.9	18.2	15.6	28.2	19.6	52.2	2.88
H	18.4	56.2	78.5	1.50	44.9	38.8	6.1	140	60.0	13.2	6.8	19.0	22.6	58.4	3.97
SEPTEMBER 19															
Surface															
A	27.2	73.6	88.2	1.35	48.2	41.4	6.8	44	50.8	13.6	11.1	19.8	26.0	54.2	6.46
B	24.7	69.5	81.5	1.34	48.4	38.2	10.2	170	52.0	11.4	8.4	31.8	26.2	42.0	6.88
C	27.4	78.5	78.5	1.39	46.0	43.0	3.0	40	28.2	15.7	15.1	17.6	26.4	56.0	6.58
D	22.6	60.0	84.6	1.33	48.4	39.6	8.8	37	48.2	11.8	8.5	39.6	25.4	35.0	8.99
E	21.0	51.1	91.7	1.27	50.3	40.8	9.5	295	51.0	19.0	12.6	39.6	30.2	30.2	10.78
F	18.5	50.1	84.0	1.33	48.0	38.1	9.9	310	52.0	10.9	7.8	45.6	21.4	33.0	7.22
G	26.9	71.4	86.3	1.32	50.1	40.4	9.7	200	46.6	11.5	9.3	31.8	27.8	40.4	9.35
H	26.2	80.5	83.2	1.44	48.5	41.7	6.8	29	29.2	14.4	15.8	12.8	22.0	65.2	4.99
Subsoil															
A	14.1	50.8	81.5	1.55	42.8	34.6	8.2	55	19.4	16.5	19.1	41.4	16.8	41.8	2.74
B	22.0	80.0	73.3	1.53	44.5	36.8	7.7	3	13.7	15.3	16.2	15.2	20.0	64.8	3.25
C	19.0	61.9	82.1	1.52	44.5	40.3	4.2	24	18.5	16.4	18.1	13.6	20.8	65.6	4.01
D	18.5	76.3	57.0	1.61	40.5	35.2	5.3	7	8.1	7.9	8.5	44.6	13.6	41.8	2.46
E	21.2	72.2	79.5	1.50	45.0	42.5	2.5	Nil	28.4	19.7	14.7	11.6	22.0	66.4	3.87
F	18.6	55.0	77.7	1.45	46.9	41.9	5.0	37	13.4	14.0	13.3	12.2	18.4	69.4	3.40
G	23.2	76.3	89.9	1.50	44.1	41.7	2.4	Nil	34.6	24.4	17.9	21.8	18.6	59.6	3.27
H	21.1	60.8	86.8	1.51	45.0	44.5	0.4	13	51.9	10.5	10.0	11.4	21.6	67.0	3.13

amount retained by different sieves upon wet-sieving. The variability in the measurements due to factors of all kinds, particularly moisture content, effectively hides any seasonal change in these measurements also.

The observations of Aldefer (1) enabled him, for Hagerstown silt loam, to detect changes in percentage of 0.25 mm. water stable aggregates due to seasonal effects, the percentage increasing in the late autumn (November) and also during the late winter (February). In our experiments there is good evidence that micro-aggregation in the surface soil increased slightly but steadily during the summer, the maximum percentage of aggregation being found in the September sampling. Subsoils showed higher aggregation towards the end of July, but the results are inconclusive.

Field Notes Related to Laboratory Measurements

Although field notes have been omitted from this report in order to save space, a few comments may be made thereon. It is possible to relate field notes to objective laboratory measurements, wet-sieving results being the most promising. It is noted that when the size of the aggregates, estimated by eye for the surface soil in the field, is compared with the amount of material retained on the coarse (No. 10) sieve, qualitative agreement was found, i.e., more soil was retained where the estimated crumb size was large. For the subsoil horizon the effect is similar, but different in degree. Here observations in the field indicated average granule size in the subsoil to be slightly, but not greatly, smaller than in the surface regions. Upon wet-sieving, however, considerably smaller portions of subsoil were found upon the coarse sieve; in other words, the subsoil granules possessed a lower water stability.

Field notes suggest that granulation improved with the advancing season. There is no clear evidence of this in the sieving results, but measurements of micro-aggregation for surface soils did show an increase with the advancing season. Micro-aggregation of the subsoil was maximum in the July 25 measurements. Whenever observations indicated more than usual sand, micro-aggregation measurements showed reduced values; when particularly hard cubic structure was observed in the subsoil micro-aggregation was high; it was also higher in the subsoil if grass roots were in evidence. The last mentioned observations are what one would expect.

In general, observational data were borne out by laboratory measurements.

The Effect of Air Drying

Changes in certain of the measurable structure properties begin to take place as soon as the soil is disturbed for sampling. In the Ste. Rosalie clay some of these changes, micro-aggregation for example, take place very rapidly in the early stages—an effect which can easily destroy the value of otherwise careful measurements. As a rule it is not convenient to perform analyses "immediately" after field sampling, and failing this one is led to the alternate plan of working with air-dry samples. Alderfer has pointed out that this practice,while reducing all measurements to a common basis, nevertheless obliterates to a considerable extent differences in aggregation which are easily detected when the soil is analysed at the field-moist condition.

While structural differences were usually found to be reduced by air drying, sometimes they were enhanced. As far as the wet sieving experiments are concerned, there is generally fair correlation between results obtained before and after air drying. This is not equally good for the different sizes of aggregates, nor is it equally good at the different sampling dates. In general it appears that wet sieving at field moisture has given a greater proportion of the larger aggregates in both surface and subsoil samples. Air drying has increased the amount passing all three sieves. There is no doubt that air drying, followed as it was by extra handling, including some clod-crushing and sieving through the 4 mm. sieve, would tend to increase the percentage of small aggregates. It seems difficult to avoid this extra handling because even with the technique chosen it was not easy to obtain satisfactory sampling. The problem of sampling itself is a serious one and requires further study.

Along with the differences just mentioned there is the question of degree of correlation. This has not been put to a statistical test, but it appears that best correlation between field-moist and air-dry analyses are found for material on the largest and again on the smallest sieve. The results for the medium sieve were uniformly scattered. In like manner better correlation is observed for sampling dates other than July 25. On this date the field samples were actually drier than at any other sampling date, and hence might have been expected to show least change upon air drying. The opposite was in fact observed. The effect of air drying is evidently quite complex.

Relations between Physical Properties

The factors which are responsible for aggregation are many and varied. Both Russell (17) and Baver (2) have discussed the problem in some detail and recently Alderfer (1) has presented experimental measurements of considerable value on the aggregation of Hagerstown silt loam. These latter measurements were made upon a soil which had been given a variety of surface treatments, whereas the present study sought to examine the effects modified only by seasonal changes and the natural variation of the soil samples.

In attemping to follow seasonal influences it is evident that soil variability is a serious handicap. Soil variation was anticipated at several sampling points which were deliberately chosen near a drainage ditch across one end of the field, but other regions, far from disturbing influences, showed variations of considerable magnitude.

This very fact offers an opportunity to examine the effect of soil variation. A large number of scatter diagrams were prepared to trace the relative dependence of the various soil properties upon one another. The scatter varied widely—ranging from indications of no dependence to the fairly high degree of dependence shown in Figure 2 where the correlation between non-capillary porosity and the logarithm of percolation rate is depicted. The connection between these two properties is quite definite and it is safe to conclude that the non-capillary porosity determines the percolation rate irrespective of time of sampling or position in the field.

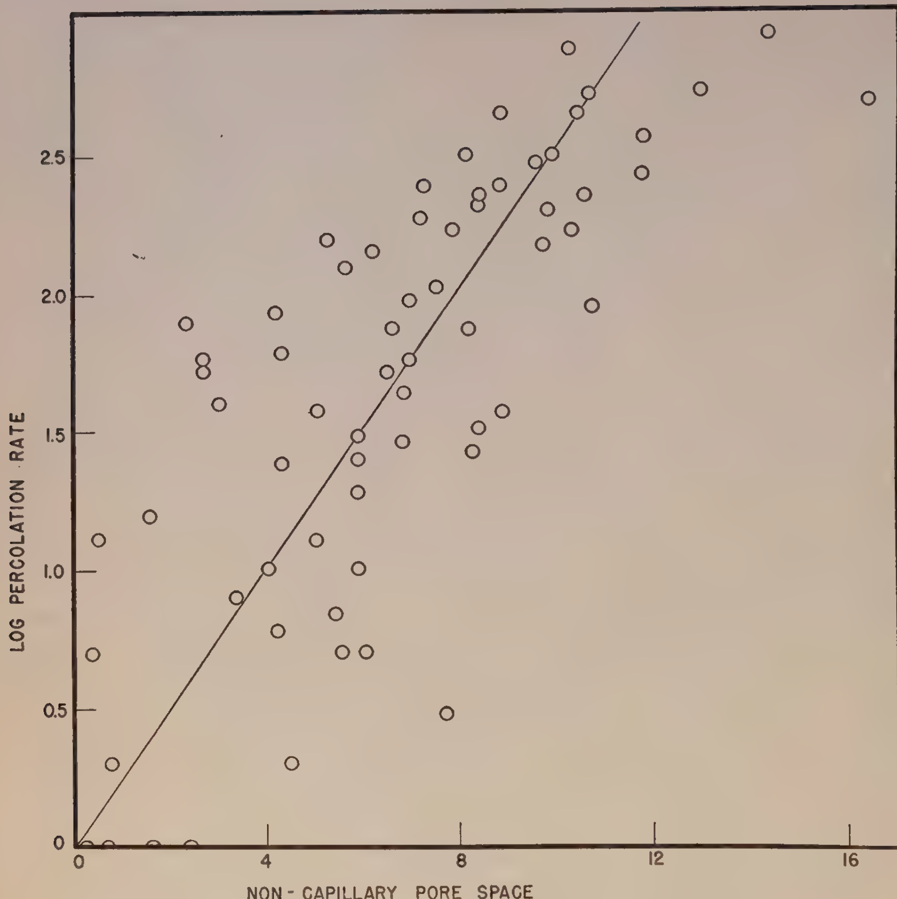

FIGURE 2. Scatter diagram to show relationship between Non-capillary Pore Space and the Logarithm of the Percolation Rate. (The straight line drawn among the points is not necessarily the one of best fit.)

What particular components determine non-capillary porosity and percolation rate is a natural question. The answer is not obvious, but it may be obtained from a careful study of the experimental data. While it is not always possible to distinguish between cause and effect, the contributing factors which might reasonably be considered to be the chief independent variables in the problem are: Percentage of sand, silt and clay, the quantity and nature of organic matter, the real specific gravity and shape of the soil particles and the moisture content. These factors, under the influence of micro-organisms and with the elapse of time, produce a certain aggregation which will have its concomitant pore space, volume weight and permeability. Several of the factors are included in this study and they may be combined as follows:

If moisture as a percentage of saturation (A), loss on ignition (B), and clay content (C), be chosen as independent variables, the contribution of these three to the dependent variable (D), non-capillary pore space may be evaluated. By the method of Wallace and Snedecor (20) Table 2 has been obtained from the 76 sets of experimental values.

TABLE 2.—CORRELATION COEFFICIENTS BETWEEN PHYSICAL PROPERTIES OF 76 SOIL SAMPLES

A Moisture, percentage saturation
B Loss on ignition, %
* Significant, P = 0.05
C Clay content, %
D Non-capillary pore space, %
** Highly significant P = 0.01

Pair	Simple correlation coefficient	Partial correlation coefficient
A B	−0.2943	−0.0011
A C	0.2848	−0.0074
A D	−0.5307	−0.4308**
B C	−0.4299	−0.1820
B D	0.5549	0.3815**
C D	−0.5465	−0.3729*

The simple correlation coefficients indicate that all the variables are associated and interrelated. The partial correlation coefficients represent a measure of the association between each pair, independent of the accompanying variation in the other variables. It is found that three of the partial coefficients are significant. It may thus be seen that non-capillary pore space is indeed dependent upon the clay content, the percentage of moisture present and the quantity of organic matter in the soil.

To study the relationship further the regression equation for non-capillary pore space (D) in terms of the independent variables, moisture (A), loss on ignition (B), and clay content (C), has been calculated. The result is:

$$D = 13.6 - 0.084\,A + 0.39\,B - 0.078\,C$$

The coefficients of A, B and C are all significant and the multiple correlation coefficient may be found, $R = 0.897$, indicating a reasonably good fit.

It is clear from the regression equation that as loss on ignition increases, non-capillary porosity increases, whereas when moisture or clay content increases, the porosity is reduced. From the regression equation it may also be deduced that the contribution made toward non-capillary porosity by each of the three independent variables is approximately equal, the calculated proportions being 36, 33 and 31 per cent for moisture, loss on ignition, and clay, respectively. Allowing for errors in the estimates this means that one per cent rise in ignition loss will have approximately the same effect upon the non-capillary pore space as will a decrease of one per cent in either moisture or clay content.

The effect of organic matter is not surprising because it has been shown in this laboratory (14, 16) to have a dominant effect upon many physical properties of Quebec soils, while clay was found to play a minor part in determining the properties measured for the fairly large group of soils studied.

As far as non-capillary pore space and percolation rate are concerned, it is now evident that clay and organic matter play approximately equal roles in the Ste. Rosalie clay soils. Moreover, a change in the moisture content has its own very considerable effect. It is clear therefore that moisture content must be controlled or carefully specified in order that pore space measurements shall have meaning.

SUMMARY

The structure of Ste. Rosalie clay has been studied by direct observation and by measurements of volume weight, capillary pore space, non-capillary pore space, micro-aggregation, macro-aggregation, permeability to water-flow, texture and loss on ignition.

Considerable variation was found at different times and different places on the test field; micro-aggregation was found to increase somewhat toward the end of the growing season.

The effect of air-drying, before analysis, upon the various physical properties of the soil was found to be complex.

Percolation rate was found to be closely related to non-capillary pore space.

Non-capillary pore space was shown to depend upon (1) the moisture content of the soil at the time of sampling (expressed as a percentage of the amount required for saturation), (2) the organic matter (expressed as the percentage loss on ignition) and (3) clay content (expressed as a percentage of air dry weight).

If the four variables referred to in the previous paragraph are designated by D, A, B and C, respectively, the regression equation is found to be:

$$D = 13.6 - 0.084\,A + 0.39\,B - 0.078\,C$$

with multiple correlation coefficient of 0.897. It follows that non-capillary porosity, and hence permeability to water, is influenced to about the same extent by texture, moisture and the content of organic matter in this type of soil.

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THE ROOTING OF CYPRESS AND ROSE CUTTINGS AS INFLUENCED BY ARASAN, FERMATE, AND SPERGON, AND EACH FUNGICIDE IN COMBINATION WITH NAPHTHALENE ACETIC ACID[1]

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Studies of the influence of Arasan, Fermate, and Spergon upon cypress and rose cuttings were initiated because Arasan and Spergon, and Arasan in combination with naphthalene acetic acid, had exerted favourable effects in the propagation of hyacinth bulbs (1). In view of the evidence (2, 3, 4) that the fungicide ethyl mercuric phosphate has promoted rooting in some but not in all kinds of cuttings, it has appeared desirable to obtain information as to whether the organic fungicides that do not contain mercury are of value in propagation by cuttings. Furthermore, many propagators of ornamentals in British Columbia have abandoned the practice of treating cuttings with naphthalene acetic acid and other root-promoting substances, partly because root stimulation by such substances is followed frequently by a high mortality among the rooted cuttings. This high mortality was noted by Grace (5) after the treatment of *Dahlia* cuttings with naphthalene butyric acid solutions. Greater mortality was observed when the root-promoting substance was applied as a water solution than when mixed with talc and applied as a dust, and evidence was presented of protection against mortality by talc alone. The possibility cannot be ignored that the death of cuttings is due in part to invasion by fungi or bacteria, and that mortality may be reduced by combining the root-promoting substance with a suitable fungicide. However, the investigations of Grace and his associates (2, 3, 4) have suggested that the influence of the fungicide ethyl mercuric phosphate is due to a physiological rather than to a fungicidal effect.

Four hundred cuttings of Lawson cypress, *Chamaecyparis Lawsoniana* (A. Murr.) Parl. var. *Allumi* (R. Smith) Beiss., were taken from a single tree, and divided into eight groups of fifty each. One group was treated with Arasan, another with Fermate, and a third with Spergon, by dipping the bases of the cuttings into the fungicides in their dust form. Three groups were treated in a similar manner, except that the fungicides were combined with naphthalene acetic acid. The combination was prepared by adding 1 ml. of a solution of naphthalene acetic acid containing 10 p.p.m. to 5 gm. of each fungicide. One group was planted without treatment to serve as a control, and the remaining group was immersed for 1 hour in a solution of naphthalene acetic acid to serve as a second control.

One hundred and fifty cuttings were taken from a single rose bush, a Hybrid Tea climber, Hoosier Beauty, and divided into groups of twenty-five each. Three groups were treated with the three fungicides in combination with naphthalene acetic acid, each group with a different fungicide. Three other groups were planted without treatment.

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All cuttings were planted in a mixture of clean sand and peat, and were maintained in a cool greenhouse until adequate evidence was secured of survival or death.

The influence of the treatments on cypress cuttings is shown by the data in Table 1. The loss of cuttings through failure to root was diminished greatly by dipping the bases of the cuttings in Arasan, Fermate, or Spergon dusts. Fermate and Spergon were significantly superior to Arasan in the promotion of rooting. The inclusion of a trace of naphthalene acetic acid with each dust appeared to diminish slightly their effectiveness. However, the decrease in effectiveness was only significant when the acid was combined with Fermate. The loss of cuttings was also greatly diminished by immersing the cuttings for one hour in a solution of naphthalene acetic acid containing 10 p.p.m. This treatment, however, did not appear to promote rooting and survival so effectively as the dry dust treatments with Fermate or Spergon.

The treatments of the rose cuttings had no significant effect. Within a period of two months over 80 per cent of the treated and control cuttings had rooted, and consequently the study was abandoned.

TABLE 1.—THE ROOTING OF CYPRESS CUTTINGS AS INFLUENCED BY ARASAN, FERMATE, AND SPERGON, AND EACH FUNGICIDE IN COMBINATION WITH NAPHTHALENE ACETIC ACID

Treatment	Number of rooted and dead cuttings after					
	61 days		99 days		131 days	
	Rooted	Dead	Rooted	Dead	Rooted*	Dead
Arasan	9	1	13	10	18	32
Fermate	12	2	21	16	32	18
Spergon	5	0	19	12	30	20
Arasan and N.a.a.**	12	0	18	24	25	25
Fermate and N.a.a.	10	0	12	28	16	34
Spergon and N.a.a.	12	0	15	24	26	24
Control (no treatment)	0	4	0	23	3	47
Control (N.a.a. alone)	16	4	19	27	23	27

* A difference of 8 is required in the number of rooted cuttings after 131 days to attain a 5 per cent level of significance.
** N.a.a. = Naphthalene acetic acid.

Although the treatment with Fermate or Spergon proved to be more advantageous than an immersion treatment in a naphthalene acetic acid solution, the conclusion cannot be drawn that the Fermate or Spergon dust treatments are superior to treatments with the common class of substances often designated as phytohormones. However, ample evidence exists that the efficiency of the phytohormones depends upon a number of factors, including the nature of the substance, the concentration, and the manner in which the substance is applied to the cuttings. Since these factors are not well known, the average propagator would probably obtain more satisfactory results by following the simple practice of dipping the bases of Lawson cypress cuttings in either Fermate or Spergon dusts.

No satisfactory explanation can be offered as to why treatments with Fermate or Spergon dusts promoted the rooting of Lawson cypress cuttings to such a remarkable extent. If the fungicides protected the cuttings

against parasites, such protection might enable them to survive for a sufficient period to produce roots. However, parasitism is not likely to occur in mixtures of clean sand and peat, and no evidence of attack by fungi, bacteria, or other parasites has been found.

SUMMARY

The loss of cypress cuttings of *Chamaecyparis Lawsoniana* (A. Murr.) Parl. var. *Allumi* (R. Smith) Beiss. was greatly diminished by dipping their bases into Fermate or Spergon dusts and by immersing the cuttings for one hour in a solution of naphthalene acetic acid containing 10 p.p.m. prior to planting. The loss was diminished to a slightly greater degree by the Fermate and Spergon treatments than by treatments with the fungicides in combination with a trace of naphthalene acetic acid. Although loss was reduced by the application of Arasan dust, this fungicide did not favour rooting to the same extent as Fermate or Spergon.

Similar treatments of rose, Hoosier Beauty, cuttings had no significant effects. Regardless of treatment, practically all cuttings rooted within a period of two months.

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SOIL COLLOIDS

V. EFFECT OF FIELD APPLICATIONS OF LIME AND MANURE[1]

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That fraction of the soil which is designated by the term "colloids" is recognized as the seat of many reactions which take place within the soil body. Among the properties attributed to the colloidal fraction are those of base exchange, adsorption and retention of plant nutrients, reactivity toward chemical reagents, solubility, heat of wetting and water holding capacity (5). Bouyoucos (6) believes the physical properties of soils are largely controlled by the colloidal material while Truog (11) has indicated the function of soil colloids in plant nutrition. More recently Jenny and Overstreet (8) have suggested that cations are interchanged by plant roots and soil colloids while Papadakis (9) has commented on the effect of soil colloids on plant growth. Some of the theories concerning the formation, structure and behaviour of soil colloidal material, the importance of which is generally recognized, have been reviewed by Atkinson (1).

Tyulin (12) has outlined a method by means of which colloids were separated from the soil in two groups. Those which, when saturated with sodium ions, were dispersed in distilled water were considered to be electronegative and were termed Group 1. After their removal, the soil residue was treated with dilute alkali and a second group, believed to be isoelectric, was obtained in two parts. Before the second part of the isoelectric colloids was dispersed, the mobile sesquioxides were removed from the soil residue by several treatments with a dilute solution of hydrochloric acid. While the exact details of Tyulin's method were unobtainable the procedure used in this investigation was worked out by Atkinson and Turner (2) based on the information given in Tyulin's paper (12). Some results obtained by using this method in a study of Canadian soils have been presented in previous papers (3, 4).

The primary objective of the present investigation was to determine the effect of lime and manure, both alone and in combination, on the colloidal complex of the soil. It was also thought that a study of this nature might yield some information as to the relationship between soil colloids and phosphorus fixation.

ORIGIN AND COMPOSITION OF SAMPLES

The soil samples used in this study were collected in 1943 from certain plots of fertilizer experiments being conducted at the Dominion Experimental Station, Sainte-Anne-de-la-Pocatière, Quebec, and the Dominion Experimental Farm, Nappan, Nova Scotia. The cropping system of the Sainte-Anne experiment was a four-year rotation of turnips, oats, clover and timothy. In the case of the Nappan samples two were taken from dykeland where a three-year rotation of oats, clover and timothy was

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TABLE 1.—ORIGIN AND PREVIOUS HISTORY OF THE SAMPLES

Location	Treatment
Nappan, N.S. (Dykeland)	None
Nappan, N.S. (Dykeland)	Ground limestone at the rate of 2½ tons per acre in 1922, 1929, 1934 and 1940.
Nappan, N.S. (Upland)	None
Nappan, N.S. (Upland)	Ground limestone at the rate of 2 tons per acre in 1931, 1936 and 1940.
Sainte-Anne-de-la-Pocatière, P.Q.	None
Sainte-Anne-de-la-Pocatière, P.Q.	Ground limestone at the rate of 2 tons per acre in 1932, 1936 and 1940.
Sainte-Anne-de-la-Pocatière, P.Q.	Manure at the rate of 20 tons per acre in 1932, 1936 and 1940.
Sainte-Anne-de-la-Pocatière, P.Q.	Two tons of ground limestone and 20 tons of manure per acre in 1932, 1936 and 1940.

TABLE 2.—ANALYSES MADE ON THE NAPPAN AND SAINTE-ANNE-DE-LA-POCATIÈRE SAMPLES

Location	Treatment	pH	Loss on ignition	Nitrogen (N)	Phosphorus (P)
			%	%	%
Nappan (Dykeland)	Check	5.2	6.2	0.25	0.065
Nappan (Dykeland)	Limestone	6.5	6.0	0.23	0.065
Nappan (Upland)	Check	5.5	7.1	0.21	0.049
Nappan (Upland)	Limestone	6.6	7.3	0.21	0.049
Sainte-Anne	Check	6.1	6.7	0.19	0.058
Sainte-Anne	Limestone	7.1	9.7	0.30	0.085
Sainte-Anne	Manure	6.2	9.2	0.31	0.078
Sainte-Anne	Manure and limestone	7.2	8.6	0.27	0.071

practised and two were taken from upland soil which was in permanent hay. The location and previous treatment of the samples investigated, all of which were from the podzol zone (10), are given in Table 1.

The results of certain analyses, giving some general information regarding the soils, are presented in Table 2. For the Nappan samples the reactions varied from pH 5.2 to pH 6.6, the loss on ignition from 6.0 to 7.3 per cent, the nitrogen content from 0.21 to 0.25 per cent and the phosphorus content from 0.049 to 0.065 per cent. In the case of the Sainte-Anne-de-la-Pocatière samples, the pH values ranged from 6.1 to 7.2, the loss on ignition from 6.7 to 9.7 per cent, the nitrogen content from 0.19 to 0.31 per cent and the phosphorus content from 0.058 to 0.085 per cent.

SODIUM SATURATION AND pH VALUES

The pH values of the Sainte-Anne-de-la-Pocatière samples were determined with a glass electrode, both before and after saturation with the sodium ion. The results of these determinations are given in Table 3. It

TABLE 3.—EFFECT OF SATURATING SOIL WITH SODIUM IONS ON pH VALUES

Treatment	Original pH of the soil	pH of the soil after saturation with the sodium ion
Check	6.1	8.1
Limestone	7.1	9.2
Manure	6.2	8.3
Limestone and manure	7.2	9.2

TABLE 4.—COMPARISON OF AMOUNTS OF COLLOIDAL MATERIAL DETERMINED BY TWO METHODS

(Sainte-Anne-de-la-Pocatière samples)

Treatment	Colloidal material*	
	Method of Tyulin	Method of Bouyoucos
Check	9.3	9.6
Limestone	8.8	10.6
Manure	8.6	10.0
Limestone and manure	9.1	10.7

* As per cent of the air dry soil.

was thought that each soil, after saturation with the sodium ion, would have the same pH value. This was not the case. Saturation with the sodium ion increased the original pH value of the soil by 2.1 in two samples and by 2.0 in the remaining two samples regardless of the pH value of the sample before this treatment. The reason for this practically constant increase in the pH value of each sample, when saturated with the sodium ion, over the original value of the sample was not clear.

COLLOIDAL CONTENT

A method for determining the amount of colloidal material in the soil has been proposed by Bouyoucos (7). His procedure is quite different from that of fractional peptization as used in Tyulin's method (12). In order to determine how closely results obtained by these two methods would agree, the colloidal material in the Sainte-Anne-de-la-Pocatière samples was determined by each method. The results of these determinations are presented in Table 4.

In the case of the check plot the result obtained by the method of Bouyoucos was about three per cent higher than that obtained by Tyulin's method; in the three remaining samples the method of Bouyoucos gave results from 15 to 20 per cent higher. Thus it is indicated that, of the two methods used, Tyulin's gives the lower results.

TABLE 5.—AMOUNTS OF THE DIFFERENT GROUPS OF COLLOIDS

(As per cent of the air dry soil)

Location	Treatment	Group 1	Group 2a	Group 2b	Total
Nappan (Dykeland)	Check	21.7	3.4	1.5	26.6
Nappan (Dykeland)	Limestone	21.6	4.0	1.4	27.0
Nappan (Upland)	Check	3.4	4.4	0.9	8.7
Nappan (Upland)	Limestone	3.8	4.5	0.9	9.2
Sainte-Anne	Check	3.5	5.0	1.9	10.4
Sainte-Anne	Limestone	3.1	3.9	2.2	9.2
Sainte-Anne	Manure	2.6	4.8	2.1	9.5
Sainte-Anne	Manure and limestone	3.3	3.9	1.6	8.8

TABLE 6.—DISTRIBUTION OF PHOSPHORUS IN THE DIFFERENT GROUPS OF COLLOIDS

(As per cent of the total phosphorus of the soil)

Location	Treatment	Group 1	Group 2a	HCl treatment	Group 2b	Residue	Percentage recovery
Nappan (Dykeland)	Check	49.1	12.7	0.80	17.3	17.1	97.0
Nappan (Dykeland)	Limestone	38.2	8.8	1.00	17.0	16.3	81.3
Nappan (Upland)	Check	21.8	34.7	0.40	11.8	24.6	93.3
Nappan (Upland)	Limestone	20.7	34.6	0.30	13.5	25.2	94.3
Sainte-Anne	Check	17.1	36.8	0.29	12.6	36.3	103.1
Sainte-Anne	Limestone	12.6	33.0	0.20	14.5	41.7	102.0
Sainte-Anne	Manure	14.6	38.9	0.14	12.5	35.0	101.1
Sainte-Anne	Manure and limestone	19.2	30.8	0.16	14.9	36.5	101.6

COLLOIDAL FRACTIONATION AND PHOSPHORUS DISTRIBUTION

The amounts of the different groups of colloids obtained from the eight soils investigated are given in Table 5. It is apparent that the dykeland soils contained more Group 1 and more total colloids than did upland soils from the same location or from a different location in the same soil zone. In the case of the two upland soils from Nappan and the four soils from Sainte-Anne-de-la-Pocatière, the sum of Groups 2a and 2b colloids exceeded the amount of Group 1 colloids in each case. This was in agreement with Tyulin's results (12) which showed that podzol soils contained more isoelectric than electronegative colloids. The results presented in Table 5 indicate that applications of lime and manure, either alone or in combination, did not significantly affect the total colloidal content of the soil or the distribution of the colloids among the groups.

The distribution of the soil phosphorus among the different groups of colloids and the residue left after the removal of the colloids is given in Table 6. The two dykeland soils had a much larger percentage of their phosphorus in Group 1 and a smaller percentage in Group 2a and in the residue than did any of the other samples. These two soils also had a slightly larger percentage of phosphorus in Group 2b than did any of the others. The distribution of phosphorus in the two Nappan upland soils was similar to that of the four Sainte-Anne samples. In the last mentioned

TABLE 7.—RELATIONSHIP BETWEEN THE AMOUNT OF GROUP 1 COLLOIDS, THEIR PHOSPHORUS CONTENT AND CROP YIELDS

Location	Treatment	Per cent Group 1 colloids in the soil	Per cent of total phosphorus in Group 1	T. hay per acre (clover and timothy)
Nappan (Dykeland)	Check	21.7	49.1	2.06 (15 yr. av.)
Nappan (Upland)	Check	3.4	21.8	1.02 (13 yr. av.)
Sainte-Anne	Check	3.5	17.1	0.92 (19 yr. av.)
Sainte-Anne*	Manure	2.6	14.6	2.15 (19 yr. av.)
Nappan (Dykeland)	Limestone	21.6	38.2	2.74 (15 yr. av.)
Nappan (Upland)	Limestone	3.8	20.7	0.88 (13 yr. av.)
Sainte-Anne	Limestone	3.1	12.6	1.22 (19 yr. av.)
Sainte-Anne	Limestone and manure	3.3	19.2	2.47 (19 yr. av.)

six samples, approximately one-third of the total soil phosphorus was found in Group 2a. Of the four Sainte-Anne samples, the one which had received treatments of limestone and manure had the largest percentage of phosphorus in Group 1 and the smallest percentage in Group 2a. The amount of phosphorus found in the HCl treatment, prior to the removal of Group 2b colloids, was very small. In no case did it exceed one per cent of the total phosphorus in the soil and in the majority of cases it was much less. With the exception of the dykeland soils, the variation in the percentage of the total phosphorus found in Group 2b was less than the variation found in either Group 1 or Group 2a.

In the Sainte-Anne samples, the percentages of the total phosphorus of the soil found in Group 1 and in Group 2b were rather similar being approximately 10 to 20 per cent in each case. The same relationship existed between the phosphorus contents of Group 2a and the residue but these were of the order of 30 to 40 per cent. The foregoing relationships were true to some extent for the two Nappan upland soils but not for the dykeland soils.

In the two dykeland samples the colloidal material made up approximately 27 per cent of the soil yet contained about 85 per cent of the total phosphorus in the soil. In the six remaining samples the colloidal material represented about 10 per cent of the soil but contained approximately 60 per cent of its total phosphorus.

RELATIONSHIP WITH CROP YIELDS

The relationship between Group 1 colloids, their phosphorus content and crop yields is given in Table 7. In comparing the three check samples, or the three samples which received limestone alone, it is seen that the dykeland soils have a much higher content of Group 1 colloids, a much greater percentage of total phosphorus in Group 1 colloids and a greater yield of hay over a period of years, than have the corresponding soils from upland areas. Earlier results obtained in this laboratory (3) showed a relationship between greenhouse yields and the amounts of Group 1 colloids in a number of soils. In a previous publication (4) it was indicated that more phosphorus was taken up by plants from those soils which contained

a greater percentage of their phosphorus in the Group 1 colloids. Unfortunately in this study no figures were available on the phosphorus content of the crops grown. In the present investigation the effect of manure applications could be studied at only one location and here it appeared that manure increased crop yields without having a similar effect on the amount of Group 1 colloids.

SUMMARY

The effect of applications of limestone and manure, alone and together, on the colloidal content of the soil was investigated. Eight soil samples from three fertilizer experiments were used.

The effect of saturating soil with the sodium ion on the pH value was studied. It was found that this treatment raised the pH values of two samples by 2.1 and of the other two samples by 2.0.

The colloidal material in four of the samples studied was determined by two different methods: (1) that used by Bouyoucos in mechanical analysis, (2) the fractional peptization procedure described by Tyulin. It was indicated that higher results may be expected when the colloidal material is determined by the former method than by the latter.

Applications of limestone and manure, either alone or in combination, caused no appreciable changes in the amounts of colloidal material separated from the samples studied.

Dykleland soils contained more Group 1 and more total colloids than did upland soils from the same soil zone. Furthermore dykeland soils contained more electronegative than isoelectric colloids. The opposite was true in the case of other samples from the podzol zone.

The distribution of the total soil phosphorus, among the different groups of colloids and the residue remaining after the removal of the colloids, was quite different in the dykeland soils than in any of the other samples investigated. In the case of the two dykeland samples from one-third to one-half of the total phosphorus in the soil occurred in the Group 1 colloids. In the six remaining samples Group 1 colloids contained from one-eighth to one-fifth of the total phosphorus of the soil while Group 2a colloids and the residue remaining after the removal of the colloids each contained approximately one-third of the total phosphorus content of the soil.

In the eight samples investigated the colloidal fractions separated by Tyulin's method represented from 10 to 27 per cent of the soil yet contained from 60 to 85 per cent of the total phosphorus found in the soil.

An apparent relationship was indicated between the amount of Group 1 colloids found in the soil, the percentage of the total soil phosphorus found in Group 1 colloids and crop yields.

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ERRATA

In the article, "The standard errors of different designs of field experiments at the University of Saskatchewan", by R. H. Ma and J. B. Harrington, published in the October, 1948, issue (Vol. 28, No. 10), the following errors appeared:

Page 466, second last line, phrase "according to Hunter" should be deleted, so as to read "introduced by 'Student' and discussed by Snedecor ... . .".

Page 468, line 16, "error" should read "errors."

Page 472, line 22, figure "6" should be "67."

Page 474, reference 13. "Hunter, H." should read "Student."

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